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ABSTRACT

The use of large-scale delivery systems to transmit information and skills to a large number of users at low cost is examined. A systematic review of past and current experiments with educational applications of computers and television is coupled with a study of the social milieu in which public schools can be expected to operate in the near future. The paper is divided into four sections: a general overview of the social conditions which characterize schools today, an overview of the many studies which have been done in the use of television and computers in education, and economic analysis of some of the best studies of media use in order to provide some data about the combinations of media and teacher which could produce a given "educational outcome;" and a summary of findings and implications. The report notes that while it is well established that students can learn from both television and computers, studies have not been done with an eye toward an economic product approach which would allow the determination of the best media-teacher mix to produce a given educational outcome. It is also found that certain aspects of the social milieu of present day education work against the effective use of educational technology. (JY)

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EDUCATIONAL PRODUCTION FUNCTIONS FOR TEACHER-TECHNOLOGY MIXES: PROBLEMS AND POSSIBILITIES

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Edward Greenberg

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PROGRAM ON APPLICATION OF COMMUNICATIONS SATELLITES
TO EDUCATIONAL DEVELOPMENT

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EDUCATIONAL PRODUCTION FUNCTIONS FOR TEACHER-TECHNOLOGY MIXES:

PROBLEMS AND POSSIBILITIES

Barry D. Anderson
Edward Greenberg

With An Appendix by Roger McClung

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TABLE OF CONTENTS

No. Page

Introduction. 1

I. The School System 2

A. Outputs of the U. S. School System. 2

1. Certification 2
2. Custodial Care. 3
3. Teaching. 4
4. Summary 7

B. Trends in U. S. Education 8

1. Diversification 8
2. Growth. 9
3. Reduction of Scope and Importance 10
4. Summary 12

II. Technology in the Schools 13

A. Educational Value of ITV. 13

B. Educational Value of Computer-Assisted-Instruction (CAI) 14

C. Utilization of Television and Computer-Assisted Instruction. 15

D. Prospects for Future Utilization. 17

III. Production Functions and Education. 23

A. The General Production Functions. 23

B. Problems in Specifying Production Functions 24

C. Education Production Functions Concepts 29

1. Outputs and Side Effects. 29
2. Optimizing Behavior 30
3. Relevant Learning Theory. 30

D. Education Production Functions--Evidence. 33

1. Some Problems in Obtaining Evidence 34
2. Combinations of Inputs. 37

TABLE OF CONTENTS
(continued)

No. Page

a. Denver-Stanford Spanish Course. 37
b. Sesame Street Evaluation. 38
c. Stanford CAI for Disadvantaged Children 38
d. Kiesling: Compensatory Education 40
e. Hawkridge and Associates: Compensatory Education Programs. 41

D. Summary 41

IV. Conclusions 43

Bibliography 47

Appendix: Review of Studies Using Input-Output Models to Evaluate Schools 52

1. Key to Symbols. 53
2. Summary of Studies. 54
3. Studies Summarized in the Appendix. 77

LIST OF TABLES

No. Page

I. Number of High School Graduates Compared with Population 17 Years of Age: United States, 1869-1870 to 1968-1969. . . . . 3a

II. Earned Degrees Conferred by Institutions of Higher Education: United States, 1869-1870 to 1969-1970 . . 3b

III. Gross National Product Related to Total Expenditures for Education: United States, 1929-1930 to 1969-1970 . . . . 10a

IV. Groups and Numbers of Subjects in the Analysis of the Second Semester Final 37a

V. Experimental Design 37b

VI. Sesame Street Evaluation Results. 38a

VII. Complete List of Variables Used 40a

VIII. Summary of Hawkridge's Component Analysis, 18 Successful and 25 Unsuccessful Compensatory Education Programs. 41b

LIST OF FIGURES

No. Page

1. Percent of Children Three to Five Years Old Enrolled in Preprimary Programs, by Age: United States, 1964 to 1969 . . . . 3c

2. Percent of the Schoolage Population Enrolled in School: United States, October 1950 to 1970 . . . . 3d

3a. Taxonomy of Educational Objectives: Cognitive Domain 4a

3b. Taxonomy of Educational Objectives: Affective Domain 4b

4a. Total Expenditures For Education as a Percentage of Gross National Product: United States, 1929-30 to 1969-70. . . . . 9a

4b. Salaries, Current Expense Per Pupil, and Inflation. 9b

5. Hypothetical Production Function For Fifth Grade Reading Skills 23a

6. Illustrating the Use of Production Functions in Cost Minimization 23b

7. Illustrating Substitution of T.V. For Teachers . . . 36a

8. All Disadvantaged Children Post Test Scores. 38b

9. All Children Post Test Scores. 38c

10. Isoquants Constructed For Instruction Intensity and Percentage of Instruction Given by Specialist, Holding Socio-Economic Factors and Hours Planning Constant 41a

INTRODUCTION

The purpose of this paper is to examine the possibility of applying technology to the public education system. In particular, we are interested in the application of large-scale delivery systems which could transmit information and skills to a large number of users at low cost. This interest led us to look at the possibilities for application of television and computers to education. From a systematic study of past and current experiments with educational applications of computing and television coupled with a study of the social milieu in which public schools can be expected to operate in the near future, we hoped to offer some insights into problems and prospects for the utilization of technology in education, particularly with instructional television (ITV) and computer-assisted instruction (CAI). Many other techniques have been used for instruction--language labs, still-picture, films, radio--but ITV and CAI have the potential to teach a wider variety of subject areas than virtually any other technique, and have shown themselves capable of holding the attention of people at all age levels.

We shall not be concerned very much with the technology used to distribute the TV or computer signals. Many of the results we quote are insensitive to whether the TV is distributed over-the-air, by electronic video recorder, cable, satellite, or Instructional Television Fixed Service. Educators need to form opinions on whether such tools as ITV and CAI can alleviate the problems being faced in the classrooms. The question of how to provide and distribute these services is best answered by the technologist.

The paper is divided into four sections. The first gives a general overview of the social conditions which characterize schools today; the second presents an overview of the many studies which have been done in the use of television and computers in education. In the third section, we apply economic analysis to some of the best studies of media use in order to provide some useful data about the combinations of media and teacher which could produce a given "educational" output. For the fourth, we summarize our findings and draw out the major implications.

I. THE SCHOOL SYSTEM

There is an important distinction between "education" and "school". Education is defined in Winston's dictionary as "the training of the mental or moral powers; of the knowledge and ability gained by such training". The primary definition of school is "a place where instruction is given; or an institution for learning". Figuratively, the word is also used to describe any channel through which knowledge, training, or discipline is gained, but essentially, school is a place while education is a process.

Most studies of the "educational" applications of media have examined the use of those media in schools. In so doing, they have mixed the educational applications of media with the institutional problems of schools. This mixture has serious implications for a study of the extent to which media may be used for educational purposes--the best applications of media for educational uses may be outside of schools. Having in mind that issue, let us proceed to examine outputs and trends in U.S. schools in the hope that this will help us see potential applications of technology in education.

A. Outputs of the U.S. School System

In order to examine the potential for uses of technology in schools, a description of the outputs desired from schools is required. These could be described in terms of the transmission of knowledge and/or culture from one generation to the next; however, this view is grossly oversimplified for at least two other functions are as important as the transmission of knowledge and culture: these we will call the certification and custodial functions. These are important to our study because they seriously affect the possibility of success in introducing a technology which is primarily (if not solely) intended to handle the transmission of knowledge and culture.

1. Certification

Certification refers to the function of granting degrees, diplomas, certificates and so forth, possession of which is required to perform certain tasks in society. Basically, we may distinguish two kinds of certificates: those which carry some form of legal backing (such as the requirement that one possess an M.D. degree before practicing medicine), and those which are more informal--such as an employer-imposed requirement that prospective employees have a high school diploma. Both types of certificates are important from the point of view of the person who wishes to obtain a job, although the former is more likely to have something to do with important job skills.

The scope of the certification function is shown by the number of degrees awarded. Table I shows that the number of high school degrees awarded has increased markedly over the last few years, both in absolute numbers and as a percentage of the age group likely to receive the degree. A similar trend is evident in higher education, particularly in professional degree areas, as can be seen from Table II. The number of Master's, Doctor's and first professional degrees has increased much faster than that of first or general degrees. Certification for work thus seems to be a driving force in the economy of higher education.

It should be emphasized that the certification function is conceptually distinct from job preparation. Berg's (1970) research indicates it is also distinct in practice for many occupations. However, in today's economy, those who would tinker with the education system must recognize that possession of a certificate from the "right" school is often a very important factor in choosing a mode of education. Under such conditions, if we are to develop an educational system which makes extensive use of technology, we must somehow come to grips with the certification function.

2. Custodial Care

The custodial function may be divided into two categories based largely on age. The most obvious form of custodial care is that provided by schools and day care centers which take young children "off the hands" of parents for a good part of the day. In this capacity, schools allow mothers to work and/or they permit a few hours of relaxation to people who would otherwise be burdened with children.

In the case of older children, the custodial function is more subtle. In schooling these children more emphasis is placed upon teaching, and there is widespread belief that whatever is taught is necessary for success

Table I

Number of High School Graduates
Compared with Population 17 Years of Age:
United States, 1869-1870 to 1968-1969

School Year	Population 17 Years Old[2]	High School Graduates[1]			Number Graduated Per 100 Persons 17 Years of Age
		Total	Boys	Girls	
1	2	3	4	5	6
1869 - 1870	815,000	16,000	7,064	8,936	2.0
1879 - 1880	946,026	23,634	10,605	13,029	2.5
1889 - 1890	1,259,177	43,731	18,549	25,182	3.5
1890 - 1900	1,489,146	94,883	38,075	56,808	6.4
1909 - 1910	1,786,240	156,429	63,676	92,753	8.8
1919 - 1920	1,855,173	311,266	123,684	187,582	16.8
1929 - 1930	2,295,822	666,904	300,376	366,528	29.0
1939 - 1940	2,403,074	1,221,475	578,718	642,757	50.8
1941 - 1942	2,425,574	1,242,375	576,717	665,658	51.2
1943 - 1944	2,410,389	1,019,233	423,971	595,262	42.3
1945 - 1946	2,254,738	1,080,033	466,926	613,107	47.9
1947 - 1948	2,202,927	1,189,909	562,863	627,046	54.0
1949 - 1950	2,034,450	1,199,700	570,700	629,000	59.0
1951 - 1952	2,040,800	1,196,500	569,200	627,300	58.6
1953 - 1954	2,128,600	1,276,100	612,500	663,600	60.0
1955 - 1956	2,270,000	1,414,800	679,500	735,300	62.3
1957 - 1958	2,324,000	1,505,900	725,500	780,400	64.8
1959 - 1960	2,862,005	1,864,000	898,000	966,000	65.1
1961 - 1962	2,768,000	1,925,000	941,000	984,000	69.5
1963 - 1964	3,001,000	2,290,000	1,121,000	1,169,000	76.3
1965 - 1966[3]	3,515,000	2,632,000	1,308,000	1,324,000	74.9
1967 - 1968	3,521,000	2,702,000	1,341,000	1,361,000	76.7
1968 - 1969[4]	3,622,000	2,839,000	1,408,000	1,431,000	78.4

[1] Includes graduates of public and nonpublic schools.
[2] Data from the Bureau of the Census.
[3] Revised since originally published.
[4] Preliminary data.
NOTE: Beginning in 1959-1960, includes Alaska and Hawaii.

(From Renetzky and Greene, 1971, p. 75.)

Table II

Earned Degrees Conferred by Institutions of Higher Education: United States, 1869-1870 to 1969-1970

Year	Earned Degrees Conferred			
	All Degrees	Bachelor's and First Professional	Master's Except First Professional	Doctor's
1	2	3	4	5
1869-1970	9,372	9,371	0	1
1879-1880	13,829	12,896	879	54
1889-1890	16,703	15,539	1,015	149
1899-1900	29,375	27,410	1,583	382
1909-1910	39,755	37,199	2,113	443
1919-1920	53,516	48,622	4,279	615
1929-1930	139,752	122,484	14,969	2,299
1939-1940	216,521	186,500	26,731	3,290
1941-1942	213,491	185,346	24,648	3,497
1943-1944	141,582	125,863	13,414	2,305
1945-1946	157,349	136,174	19,209	1,966
1947-1948	317,607	271,019	42,400	4,188
1949-1950	496,661	432,058	58,183	6,420
1951-1952	401,203	329,986	63,534	7,683
1953-1954	356,608	290,825	56,788	8,995
1955-1956	376,973	308,812	59,258	8,903
1957-1958	436,979	362,554	65,487	8,938
1959-1960	476,704	392,440	74,435	9,829
1961-1962	514,323	417,846	84,855	11,622
1963-1964	614,194	498,654	101,050	14,490
1965-1966	709,832	551,040	140,555	18,237
1967-1968	866,548	666,710	176,749	23,089
1968-1969	984,129	764,185	193,756	26,188
1969-1970[1]	1,025,400	785,000	211,400	29,000

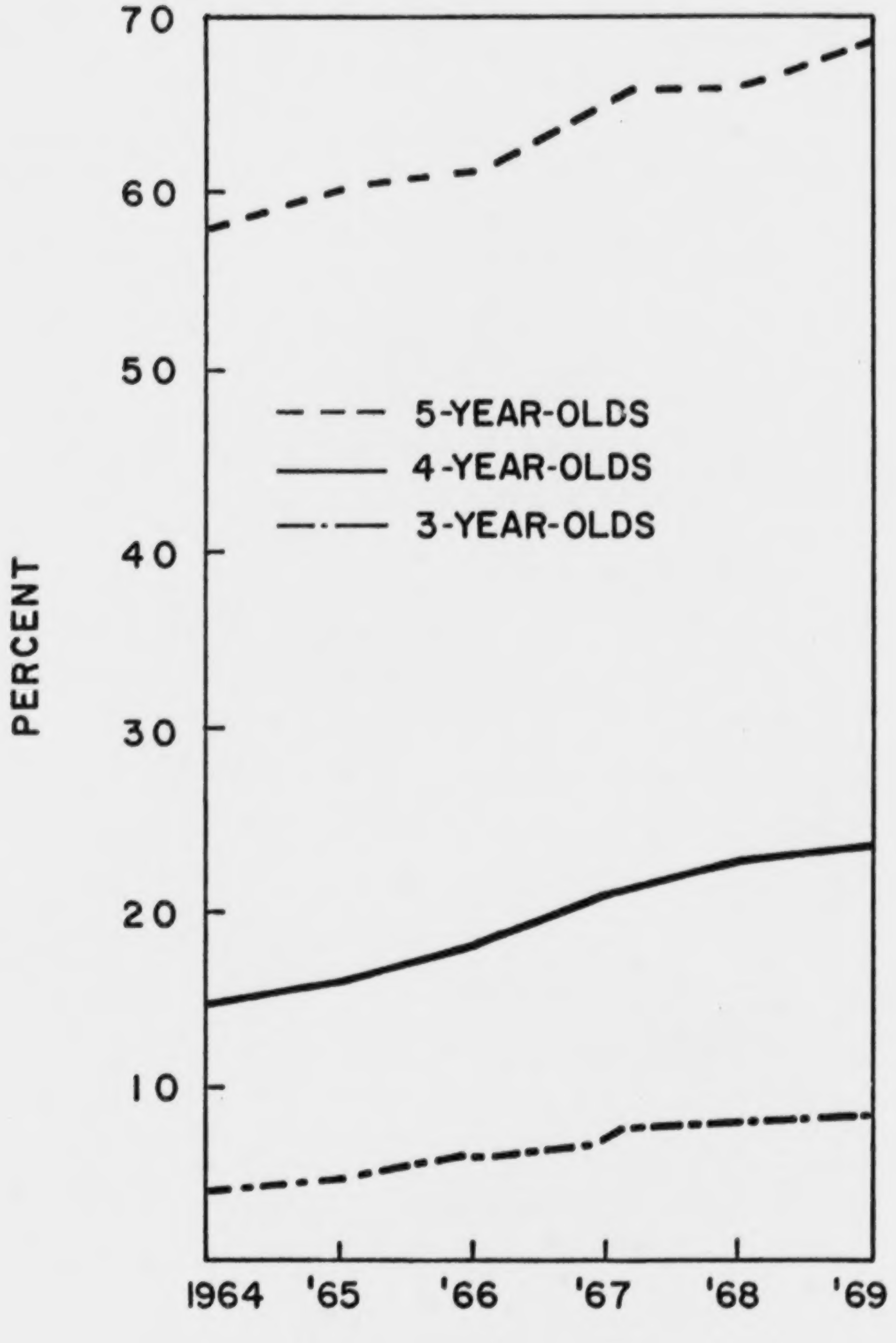
[1] Estimated by the Office of Education.

NOTE: Beginning in 1959-1960, includes Alaska and Hawaii.

(From Renetzky and Greene, 1971, p. 121.)

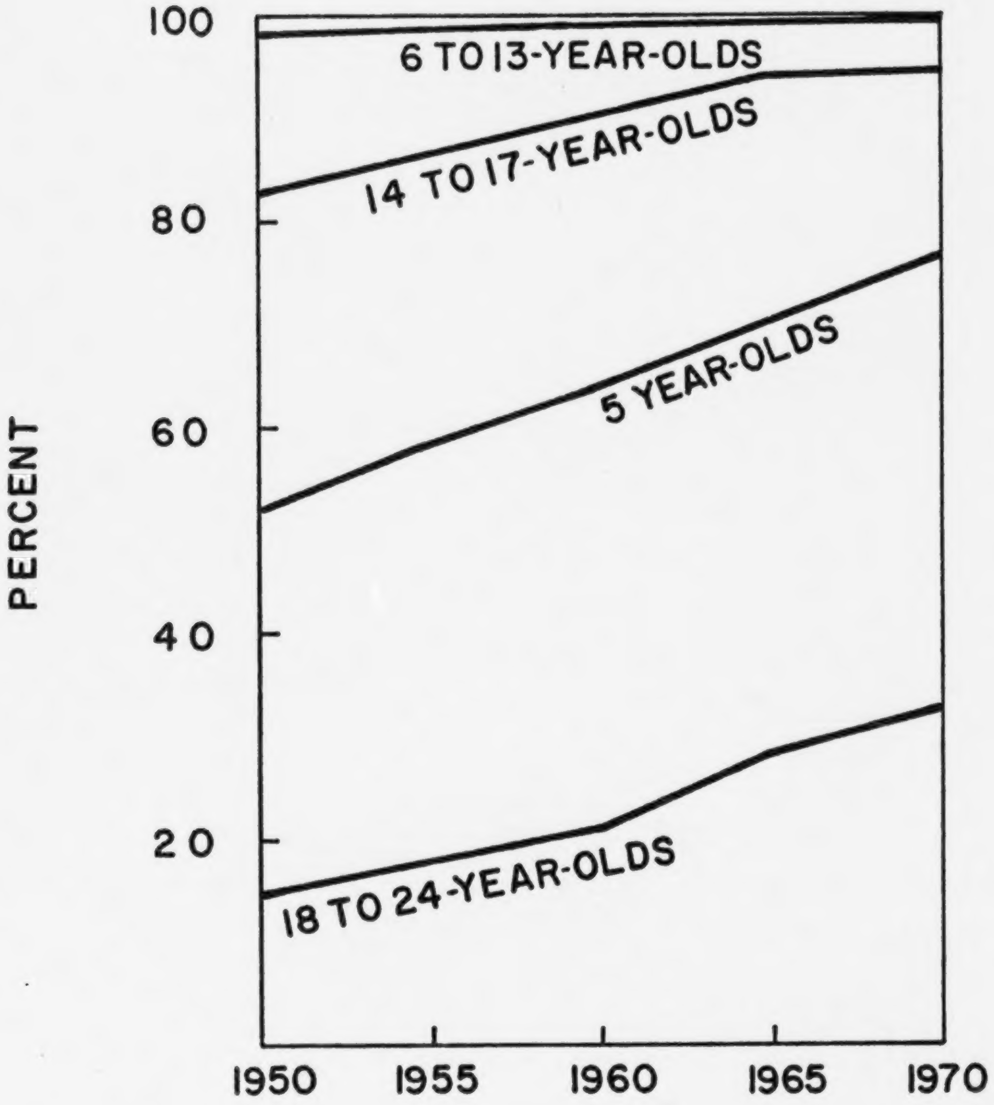
FIGURE I PERCENT OF CHILDREN THREE TO FIVE YEARS OLD ENROLLED IN PREPRIMARY PROGRAMS, BY AGE:

UNITED STATES, 1964 TO 1969



(From Renetzky and Greene, 1971, p. 72.)

FIGURE 2 PERCENT OF THE SCHOOLAGE POPULATION ENROLLED IN SCHOOL: UNITED STATES, OCTOBER 1950 TO 1970



(From Renetzky and Greene, 1971, p. 75.)

in life. To grasp the nature of the custodial function one must note that, aside from whatever is taught, schools occupy the time and energy of large numbers of people--teachers and students alike--and that in so doing they keep those people from seeking employment elsewhere in the labor market.

The scope of this function is dramatically shown in Figure 2, which shows the change in the number of persons enrolled in schools from 1950 to 1970, as a percentage of the population. This is a large change over only 20 years, and it may indicate the existence of economic and social forces which work to expand the length of time people spend in school simply because there is nowhere else for them to go.

3. Teaching

There has been a long and vigorous debate over what schools ought to teach. The debate ranges from very detailed demands for specific kinds of output (more engineers after Sputnik, for example) to descriptions of the moral characteristics that schools ought to instill in their pupils.

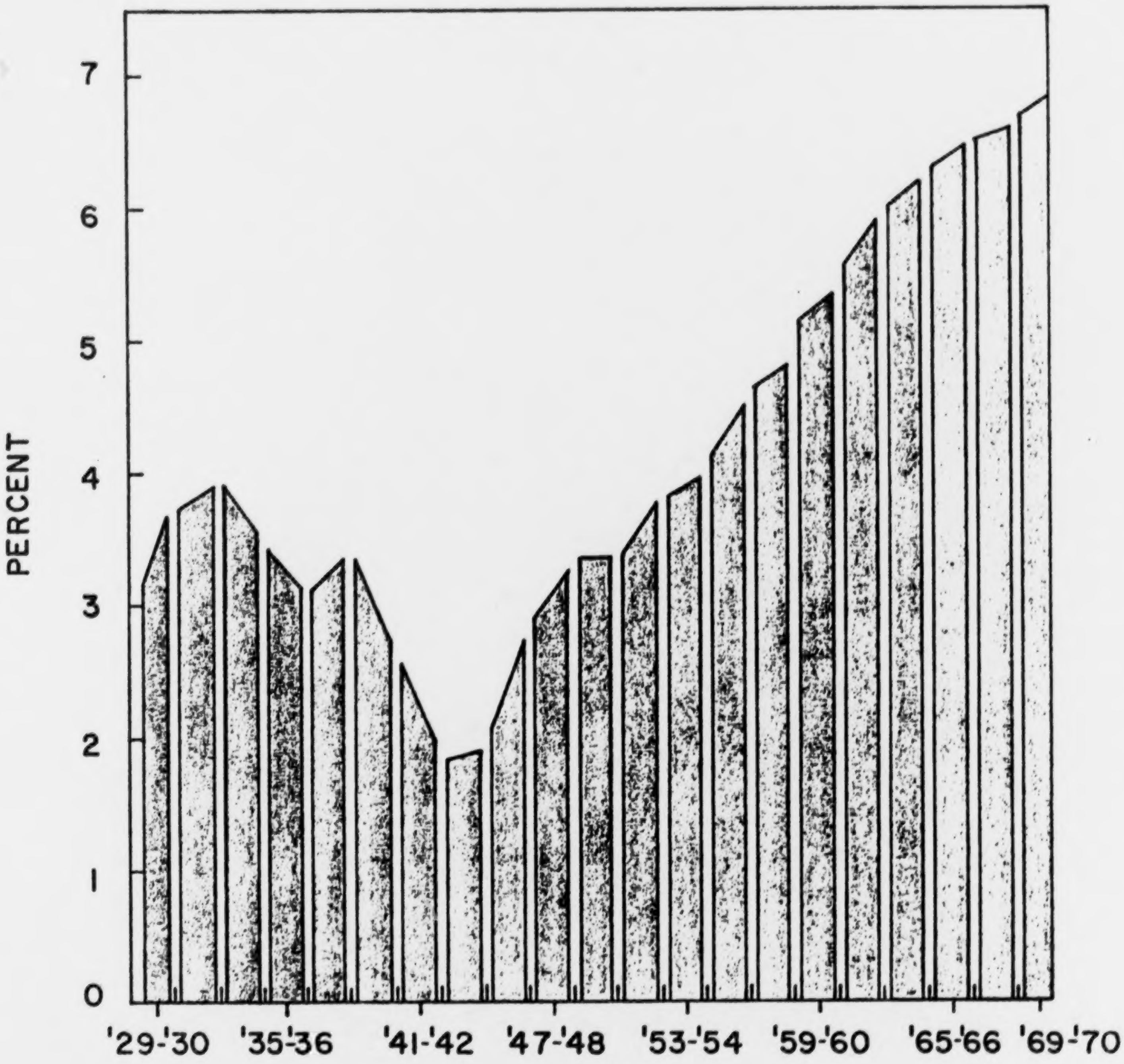
Studies of this issue are numerous; one of the better known was conducted some ten years ago by Downey (1960). Basically, Downey found that schools were primarily charged with the development of children's intellect, although the public also wanted high schools to prepare students for an occupation.

Downey's report, and others like it, suggests that while there is broad consensus about what schools are supposed to do, there is a good deal of disagreement over the details--yet it is the details which are necessary if we are to develop knowledge about how to "produce" outcomes.

Attempts to provide more detailed guidance about what should really go on in a classroom are not unknown. Perhaps the most widely used effort in this respect has been Bloom's (1956) Taxonomy of Educational Objectives. Bloom has developed two taxonomies, one for intellectual development, the other with Krathwohl et. al. (1965) for an affective domain. Both taxonomies contain objectives arranged in increasing complexity (See Figure 3).

There are problems with such taxonomies, largely because of the subtle nature of the distinctions between categories. These subtleties make it possible for a student reciting even very complex ideas to be operating at the very lowest levels of the taxonomy (because he is merely recalling

FIGURE 4a TOTAL EXPENDITURES FOR EDUCATION AS A PERCENTAGE OF GROSS NATIONAL PRODUCT: UNITED STATES, 1929-30 TO 1969-70



(From Renetzky and Greene, 1971, p. 40.)

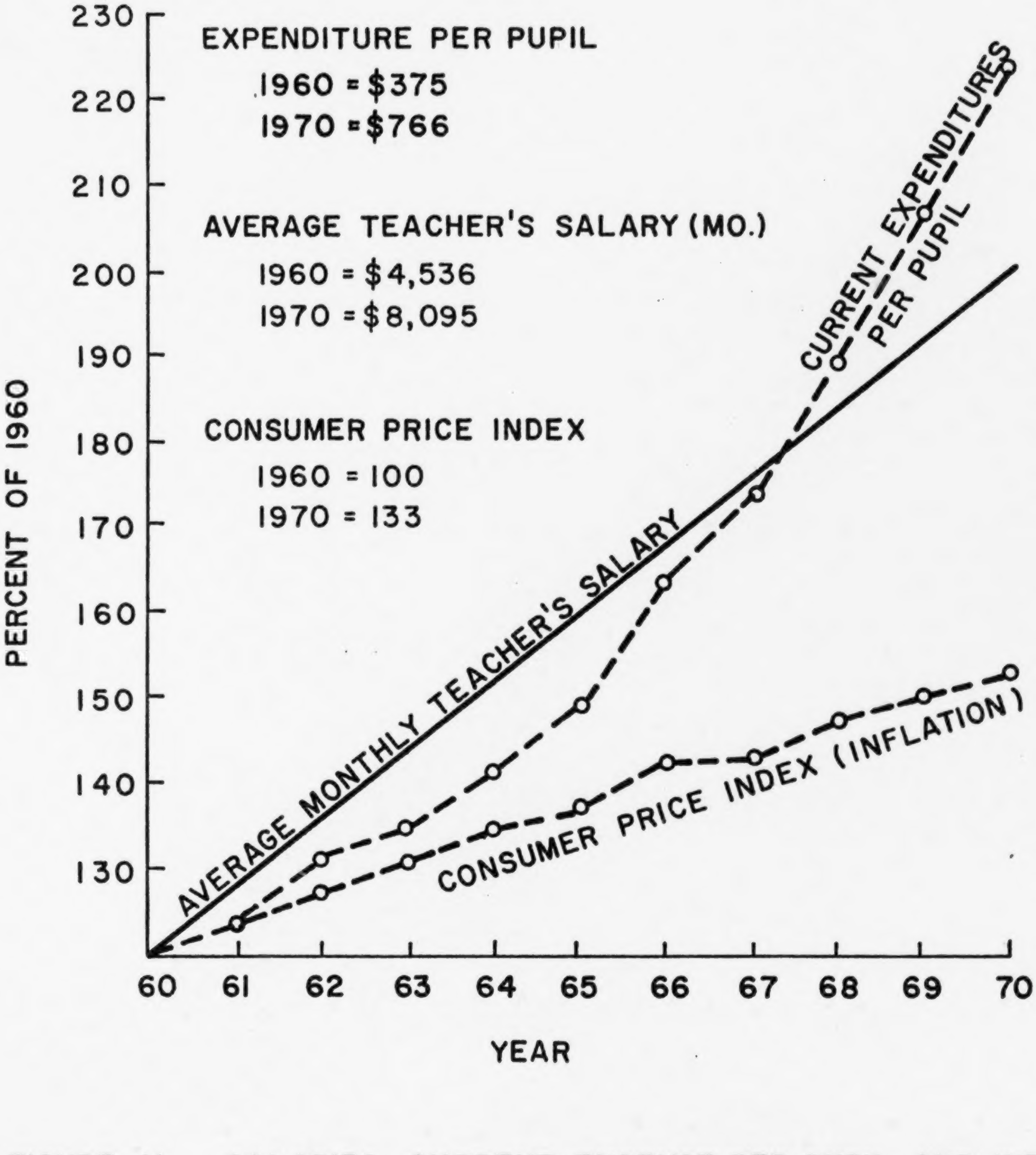


FIGURE 4b SALARIES, CURRENT EXPENSE PER PUPIL, AND INFLATION.

Figure 3a

Taxonomy of Educational Objectives: Cognitive Domain

The Cognitive Domain

The cognitive domain has six levels. They move from knowledge, the lowest level, to evaluation, the highest level.

KNOWLEDGE. Knowledge involves the recall of specifics or universals, the recall of methods and processes, or the recall of a pattern, structure, or setting. It will be noted that the essential attribute at this level is recall. For assessment purposes, a recall situation involves little more than "bringing to mind" appropriate material.

COMPREHENSION. This level represents the lowest form of understanding and refers to a kind of apprehension that indicates that a student knows what is being communicated and can make use of the material or idea without necessarily relating it to other material or seeing it in its fullest implications.

APPLICATION. Application involves the use of abstractions in particular or concrete situations. The abstractions used may be in the form of procedures, general ideas, or generalized methods. They may also be ideas, technical principles, or theories that must be remembered and applied.

ANALYSIS. Analysis involves the breakdown of a communication into its constituent parts such that the relative hierarchy within that communication is made clear, that the relations between the expressed ideas are made explicit, or both. Such analyses are intended to clarify the communication, to indicate how it is organized and the way in which the communication manages to convey its effects as well as its basis and arrangement.

SYNTHESIS. Synthesis represents the combining of elements and parts so that they form a whole. This operation involves the process of working with pieces, parts, elements, and so on, and arranging them so as to constitute a pattern or structure not clearly present before.

EVALUATION. Evaluation requires judgments about the value of material and methods for given purposes. Quantitative and qualitative judgments are made about the extent to which material and methods satisfy criteria. The criteria employed may be those determined by the learner or those given to him.

Figure 3a
(Continued)

Most of the above levels, very briefly described here, have been broken down into various subcategories. For example, under evaluation there are two categories that deal with "judgments in terms of internal evidence" and "judgments in terms of external criteria." The knowledge category has twelve separate subdivisions. As indicated earlier, there would seem to be little utility in having a teacher become conversant with these subdivisions. It is probably sufficient if the teacher simply divides the cognitive taxonomy into (a) the lowest level, that is, knowledge, and (b) all those levels higher than the lowest, that is, comprehension through evaluation. Even this rough, two-category scheme will allow a teacher to identify the proportion of his objectives that fall into the lowest level category. And this seems to be the most important advantage of the cognitive taxonomy--namely, encouraging the teacher to identify what proportion of his objectives are at the very lowest level. Unfortunately, far too many of the objectives currently used in the schools require only recall on the part of the learner and can be aptly classified as merely knowledge objectives. There is nothing intrinsically wrong with knowledge, but if this is all we are asking of students, we probably should set our sights somewhat higher.

Source: Popham, 1970, p. 33-34.

Figure 3b

Taxonomy of Educational Objectives: Affective Domain

The Affective Domain

The affective domain is subdivided into five levels. These levels in particular may cause the teacher much difficulty in classifying objectives. Once more, these levels may have some value in that they encourage the teacher to think about different forms of objectives, but it is not recommended that the teacher devote too much time in attempting to classify various objectives within these levels.

RECEIVING (Attending). The first level of the affective domain is concerned with the learner's sensitivity to the existence of certain phenomena and stimuli, that is, with his willingness to receive or to attend to them. This category is divided into three subdivisions that indicate three different levels of attending to phenomena--namely, awareness of the phenomena, willingness to receive phenomena, and controlled or selected attention to phenomena.

RESPONDING. At this level one is concerned with responses that go beyond merely attending to phenomena. The student is sufficiently motivated that he is not just "willing to attend," but is actively attending.

VALUING. This category reflects the learner's holding of a particular value. The learner displays behavior with sufficient consistency in appropriate situations that he actually is perceived as holding this value.

ORGANIZATION. As the learner successively internalizes values, he encounters situations in which more than one value is relevant. This requires the necessity of organizing his values into a system such that certain values exercise greater control.

CHARACTERIZATION BY A VALUE OR VALUE COMPLEX. At this highest level of the affective taxonomy internalization has taken place in an individual's value hierarchy to the extent that we can actually characterize him as holding a particular value or set of values.

The definitions for the affective taxonomy are clearly far less rigorous than for those of the cognitive taxonomy, and those who work with the cognitive taxonomy often suggest that these affective levels need much more precision. Both of these taxonomies have been presented, however, because they are in common use today, and it may be that if the teacher becomes more familiar with them he will find them of some utility. While an extensive reading of the original taxonomies is not necessary, some teachers may find this a useful enterprise.

Source: Popham, 1970, p. 34-35.

ideas that someone else has given him) while a student operating at the high levels may be working with ideas familiar to a teacher and be judged to be operating at low levels of development. Nor is it clear how any of the taxonomy objectives relate to the broader tasks of public education outlined by Downey.

Despite the recent emphasis on the notion of different levels of intellectual, emotional, and physical development, there has been little systematic research into just how these levels may be developed in students. This is partly due to the novelty of the approach in the field of education, but more importantly, it seems to be due to an inability on the part of educators and the public at large to arrive at some sort of consensus about the characteristics of an "educated" man.

On a less philosophical plane, there have been some efforts to examine what the schools do. A major attempt at assessment is the Coleman report (Coleman _et al._ 1966). The report is massive and not easily summarized, but the main conclusions in regard to the teaching function of schools appear on pages 21 and 22. They may be paraphrased as:

1) Schools are remarkably similar in the way they relate to the achievement of their pupils, allowing for the students' socioeconomic background. Moreover, the socioeconomic factors bear a strong relation to academic achievement.
2) The effects of schools differences in relation to the various racial and ethnic groups; for example, the achievement of white students is less sensitive to school characteristics than that of minority students.
3) Variations in facilities and curriculums account for relatively little variation in pupil achievement.
4) Quality of teachers - measured by verbal ability, education, and parent's education - shows a stronger relationship.
5) Pupil's achievement is strongly related to the educational background and aspiration of other students in the school.

While the study is controversial (see, for example Dyer, 1968), it does provide two general insights into the state of knowledge about the teaching function in schools:

1. Public schools make little or no attempt to monitor their own successes or failures. There were, at the time the report was written, no statistics which could be used to show relative expenditure per child in each school or school district in the country. More important, it was hard to find data about achievement which was collected school by school.

2. Much of the Coleman report is concerned with such inputs to the schools as libraries, teacher qualification and so forth. Perhaps this concern is legitimate in a study of educational opportunity, but the little attention paid to outputs is a reflection of the widespread belief that it is impossible to measure academic "success" in a meaningful way.

Partly in response to this educators have begun to move towards more explicit statements of objectives, and away from the mysticism which characterizes what goes on in schools. Mager seems to have led off this movement with his books, Preparing Instructional Objectives (1962), and Developing Attitude Toward Learning (1968). He and others, such as Popham (1970), and Bloom (1968), have argued persuasively that it was time educators gave up their role as mystics and began to state in clear unambiguous terms the things which students were supposed to be able to do.

Emphasizing those outputs which are easily quantified may result in a slighting of subject matter, or attitudes in which progress is not easily measured. Silberman (1970) makes the point forcefully (pp. 196-8), but also recognizes that education includes the learning of basic skills (p. 202). In fact (p. 62) he faults slum schools relative to middle class schools for not teaching "...the intellectual skills and academic knowledge that students need if they are to be able to earn a decent living and to participate in the social and political life of the community."

In our review of the literature, hardly a single report failed to note that the objectives of education were terribly hard to specify, harder still to measure. After having made the disclaimer, practically every author proceeded to define an objective or two, measure them, and decide upon the basis of his measures whether or not a school or school system was functioning or whether TV was an effective substitute for a teacher.

Researchers are not the only people who do this. Prospective employers make some kind of assessment of employees on the basis of their education records whether or not the objectives were hard to measure. So do teachers when they assign grades on a test. School administrators resist school-by-school comparisons of achievement on the grounds that no "satisfactory" measure exists, but they also promote and fail students on the basis of those "unsatisfactory" achievement tests.

Educators generally seem quite willing to permit decisions about students' lives to be made on the basis of "unsatisfactory" achievement measures, but are unwilling to permit those same measures to be used as a basis for evaluating their own performance.[1]

In our opinion, disclaimers that the objectives of education are hard to define and hard to measure serve as red herrings to distract attention from the fact that schools have been reluctant to spell out just what objectives are to be met by teachers and students. From our perspective the reason for giving tests is not to assess or label the child, but to assess the school's performance. We recognize that there may be disagreement over the criteria to be employed in determining the outputs of a good educational system. Such things as curiosity, an open mind, and love of knowledge, belong in that category.

4. Summary

In summary, we find three functions of education: to certify students; to keep them in custody both for parts of a day and parts of their lives; and to teach skills, knowledge and attitudes desired by the society. The size and scope of the first two objectives seem well documented in standard reference works. The teaching function is so complex, and attempts to study it have been so futile, that there are few detailed descriptions about its size, scope, and success. Furthermore, although teaching is the area in which technology has the greatest potential impact, it is also the area in which there is the least financial incentive for schools to take action, since schools are usually funded on such bases as enrollment or teacher qualifications.

In economic terms, specifications for schools are on inputs, not outputs, with the exception that schools are required to take care of children and award degrees. Next to nothing about teaching output (with the possible exception of elementary reading and writing skills) seems to be required of schools by society.

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[1] This is ironic, since the tests are much more satisfactory and reliable as a basis for group-to-group comparisons where standard errors are low than for judgements about individual students where errors of measurement are extremely high.

For reasons such as these, it is hard to estimate the success or performance of schools in teaching. No data is systematically collected at national or state levels for this function, although data collected for the other two functions are used as a proxy for the teaching. This is not informative, since there is good reason to believe that not all students at a given grade possess the same skills.

What we do know, from scattered evidence, is that skills, knowledge and affective development (acculturation if you will) appear not to be equally distributed among classes, races, or intelligence levels. Little is known beyond these crude levels. There seem to be few systematic studies of the effect of schools on changing such important aspects of achievement as its distribution, variance pre-post test correlation, cost of production, or changes in absolute levels of achievement over time.

For the moment, it seems adequate to point out that schools tend to deliver best to those segments of society which have always "done well" in school. Middle and upper class students seem to receive the greatest benefit from school, while lower class students, and members of minority groups do not, in general, do as well. The picture, however, is not static. Reform movements are widespread and must be considered in order to understand the possibilities for change in the present system.

B. Trends in U. S. Education

1. Diversification

Currently there is a great deal of writing about a need to humanize the schools;[1] there is, at the same time, a move to ensure that they actually teach at least some of the skills that they say they will teach (accountability)[2]. Along with these two streams of criticism, a third advocates that schools do more for special problem areas: vocational development, "educating the culturally deprived" and so on.

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[1] See, for example, the well known works by Holt (1964), Friedenberg (1965), and Silberman (1970).

[2] See Lessinger (1970) for the best-known example of this effort.

If schools are to satisfy a significant part of this bewildering array of demands, they will have to develop new instructional strategies, for most demands are tied to failures in the most commonly used teaching strategy. Yet, in developing new strategies, schools are unlikely to forget that their "old" strategy has been successful in teaching the vast majority of students. Because of this we believe that there will be a general move towards diversity in education in keeping with the diversity of society itself. And, just as technology made diversity possible in the manufacturing industries we believe that it will be required if education is to diversify sufficiently to meet the needs of its numerous publics.

2. Growth

In addition to diversity, there are two other trends of note in American education: growth in enrollment and in cost. We showed earlier that the percent of the school age population enrolled in school has been increasing steadily over the last twenty years (the trend is actually longer than that). The extent of these figures may be shown another way: in 1967-68 there were about 122,000 elementary and secondary schools (public and private) and 2,374 institutions of higher education. Some 49,891,000 students were enrolled in the elementary and secondary schools, and 6,912,000 were in post-secondary institutions. In addition to the students, there were 2,097,000 elementary and secondary teachers and 521,000 faculty in institutions of higher education (715,000 counting administrators and other professional staff).

Cast another way the numbers may be more meaningful: in 1967-68, fully 30% of Americans were in schools as either students or teachers.[1] Numerous others, of course, were involved in schools in other ways: caretakers, textbook publishers, furniture makers, bus drivers and so forth.

Along with growth of enrollment in schools has been an increase in costs. Figure 4a shows the nature of this growth, which has been quite

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[1] The numbers are drawn from Renetzky and Greene (1971). The percentage was obtained by comparing these figures with the U.S. population given in Vital Statistics, 1969: 3-15.

steady since 1942-43. In 1967-68, the 57 billion dollars it cost to operate the public schools represented 7.2% of the gross national product. (Table III.) The growth of education costs has been faster than that of the growth of the GNP, as is generally the case in labor-intense industries. This is because manpower for education must be paid at the same scale as the manpower for increasingly productive industries, so that costs per unit of output (say graduates) rise much more quickly in education than in segments of the economy where salary increases can be offset by investment in machinery (see Coombs, 1968).

This is an important phenomenon, since it theoretically means that schools will eventually consume all of the GNP if present trends continue. The argument is fallacious since forces in the economy would act to avert such an over-concentration of resources in one sector. It is clear though that the cost of operating schools cannot continue to rise at the present rate.

As can be seen from Figure 4b, per pupil expenditures are rising faster than would be explained by inflation, indicating that the increase in costs for education over the last few years have not been attributable to increasing enrollments. This means that the anticipated decline in elementary and secondary school enrollments over the next six to ten years will not necessarily bring with it large decreases in educational expenditures, although it may slow the rate of increase somewhat.

3. Reduction of Scope and Importance

Along with economic pressures, there are also social pressures for reducing the scope and importance of schooling. Berg (1970) argues that the role played by schools in producing "success" for their graduates depends largely upon the number of graduates, rather than on what the schools do to the students. His case, grossly oversimplified, is that the "need" for an education in order to get a job is a function of the supply of overeducated people, rather than of increasingly complex jobs. Berg's work calls into question a fundamental proposition underlying the support of public education; carried to the extreme his data suggest that education is a consumer good, purchased by affluent people in an afflucent society.

Table III

Gross National Product Related to Total Expenditures[1] For Education: United States, 1929-1930 to 1969-1970

Calendar Year	Gross National Product (in millions)	School Year	Expenditure for Education	
			Total (in Thousands)	As a Percent of Gross National Product
1	2	3	4	5
1929	$103,095	1929-30	$3,233,601	3.1
1931	75,820	1931-32	2,966,464	3.9
1933	55,601	1933-34	2,294,896	4.1
1935	72,427	1935-36	2,649,914	3.7
1937	90,446	1937-38	3,014,074	3.3
1939	90,494	1939-40	3,199,593	3.5
1941	124,540	1941-42	3,203,548	2.6
1943	191,592	1943-44	3,522,007	1.8
1945	212,010	1945-46	4,167,597	2.0
1947	231,323	1947-48	6,574,379	2.8
1949	256,484	1949-50	8,795,635	3.4
1951	328,404	1951-52	11,312,446	3.4
1953	364,593	1953-54	13,949,876	3.8
1955	397,960	1955-56	16,811,651	4.2
1957	441,134	1957-58	21,119,565	4.8
1959	483,650	1959-60	24,722,464	5.1
1961	520,109	1961-62	29,366,305	5.6
1963	590,503	1963-64	36,010,210	6.1
1965	684,884	1965-66	45,397,713	6.6
1967	793,544	1967-68	57,477,243	7.2
1969	932,100	1969-70	69,500,000[2]	7.5

[1] Includes expenditures of public and nonpublic schools at all levels of education (elementary, secondary, and higher education).

[2] Estimated. NOTE: Beginning with 1959-60 school year, includes Alaska and Hawaii.

(From Renetzky and Grene, 1971.)

Berg is not ignorant of the extensive body of literature dealing with human capital which suggests that much economic growth is due to investment in education.[1] Berg does not deal with methodological issues in his critique of these studies, but he does raise some fundamental questions about the human capital approach to assessment of economic value in education:

1. the studies measure a nation's educational input in terms of years of schooling. No attempt is made to distinguish between vocational, professional and 'academic' programs.
2. the importance of on-the-job training is almost impossible to ascertain.
3. the cross-sectional data used in the studies is unreliable as a means of determining life-time earnings.
4. the analysis of the costs of education (which is necessary if one is to compute returns on investment) is very difficult to do at anything but highly aggregated levels. (Berg, 1970; Chapter II).

Having noted these and other flaws in the human capital approach, Berg proceeds to conduct an analysis of the economic value of education at a very low level of aggregation--one which is much more useful in drawing inferences about the expected value of schooling for an individual.

Illich (1971) also argues for a reduction in the school's role in society. His rationale is complex, but the two most important points he makes are that the schools stratify society by wealth since education is costly. Second, schools teach people to depend on institutions rather than themselves for their well-being. Illich would prefer to have more emphasis placed on the individual and his capabilities.

Last, arguments raised by Jensen (1969), coupled with those of Young (1958) suggest that the schools may, unwittingly, be creating a caste system which could be at least as tyrannical as any that liberal thought has attempted to prevent. The case, simply put, is that schools play an important role in building a society based on merit. In that society only meritorious people will succeed, and only the unworthy will fail. Successful people in such a world are far more likely to obey the laws of evolution and let the unsuccessful die than were their predecessors, many of whom were incompetent and had to rely on the assistance and good will of "lesser" men in the society. Young's truly prescient book, raises the question of whether or not we should foster such a social order.

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[1] See, for example Dennison (1962) and Schultz (1962). The literature in general is reviewed in Bowman (1966).

4. Summary

The impact of these social forces on education is uncertain. Far more important as predictors of educational change are the economic pressures currently coming to bear on the schools. It is possible to argue that these forces might not operate in education. The education or knowledge industry is already the largest in the United States (cf. Machlup, 1958 for a delineation of its scope) and it has experienced very large economic growth in a very short period of time (Burck, 1964). Boudling (1971) has characterized the situation in education as possibly pathological, in the sense that the schooling industry may already occupy such an important position in the economy that the normal laws of supply and demand no longer operate. If this is indeed the case, the argument that schools will shortly come under intense and prolonged pressure to make fundamental changes in their operating procedures may be erroneous.

In any event, substantial pressures to make schools more productive are still apt to come into play. This fact alone makes the possibility of teaching by something other than a costly human professional very attractive. In view of this we next turn our attention to some of the applications of technology.

II. TECHNOLOGY IN THE SCHOOLS

We propose to consider three questions in this section: 1) What can ITV and CAI do? 2) To what extent have they been used? 3) What are the prospects for increased usage?

A. Educational Value of ITV

There has been a good deal of research designed to evaluate the effectiveness of instructional television, as a replacement for teachers. From this research, the generalization that TV and face-to-face instruction, under carefully controlled conditions, yield no differences in learning has been amply documented. The generalization has been verified at all levels of education, with a wide variety of subject matter, and under a wide variety of conditions--e.g., whether viewed in classrooms, dormitories, or at home. Moreover, companion studies designed to detect undesirable effects from TV teaching generally reported finding none. In fact ITV evaluation represents one of the largest empirical research efforts undertaken by educational researchers.[1]

The ability of television to teach effectively should not be surprising. We know that receivers are operating over six hours a day in the average home, and the first prerequisite for teaching is to obtain the attention of the learner. The combination of sight, sound, and full motion is sufficient to teach many things even without two-way communication.[2]

The unimportance of two-way communication has been explained a variety of ways: opportunities for questioning are often available after a television program; television teachers are often better at their trade than the run-of-the-mill classroom teacher; more time and energy is given over to preparation of lessons; television makes possible the use of special effects; and so on.

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[1] Much of this research is summarized by Dubin and Hedley (1969) for higher education and by Chu and Schramm (1967) for other levels. Evaluation of ITV for Army training is discussed by Kanner and his associates (1956), who also investigated how ITV could speed up the learning process.

[2] Experimental evidence summarized by Dubin, Taveggia and Thomas (1968) in their overview of research into the effect of varying class size also suggests that the mode of presentation of material is of little consequence.

All such explanations overlook the possibility that teacher activity may not have much bearing on the outcome of standardized tests. Obviously, there is a possibility that what is actually being evaluated when teachers and television are compared is the contribution of the teaching medium over and above a common textbook. If so, the contribution of the medium seems small.

B. Educational Value of Computer-Assisted-Instruction (CAI)

There is a fundamental difference between most experiments with CAI and those with television. CAI is generally regarded as a supplement to a regular course of instruction while television is frequently characterized by attempts to "Xerox" a teacher for delivery at another time or place.

CAI is also much newer and more expensive than television, a fact reflected in the paucity of evaluation and research. The technique is very much developmental, although there are some very interesting and promising experiments underway.

Two ongoing programs seem especially interesting. The University of Illinois PLATO has been used at elementary and high schools, as well as at the university level. Using pictures and audio, it has been used to teach elements of computer programming to second graders and Latin to college students. Evaluation has been rather impressionistic to this time. As software approaches a more final form, evaluation can begin.

The Stanford program in reading and arithmetic has been well documented. In general, students exposed to CAI have done better than the control group, and the program seems to work better for disadvantaged students than for middle-class suburban children. This has the socially desirable effect of distributing knowledge gains more evenly between the upper and lower classes than does "traditional" classroom instruction (see Jamison *et al.* 1971). A fascinating description of the trials, tribulations, and joys of working with such a system may be found in Suppes *et al.* (1968).

Basic descriptive information on the use of CAI in secondary schools may be found in *Survey of Computer Utilization in Secondary Schools*.

Fairly large scale experiments have been undertaken in Waterford and New York City, but final reports have not been issued. In addition, a large number of small scale experiments have been undertaken. For example, a basic psychology statistics course taught by CAI enabled the students to achieve the usual performance level in a fraction of the time an ordinary lecture series took.

Generally, evaluation of CAI seems to indicate differences between those groups exposed to CAI and those not exposed favoring use of the computer. These results are still too small in number and too likely to show the "Hawthorne Effect" to justify large-scale adoption of computers, especially given their high costs of installation and operation. However, experiments to date do indicate a very promising future for CAI.

C. Utilization of Television and Computer-Assisted Instruction

To put it bluntly, neither television nor computers are widely used for instructional purposes in schools, particularly in elementary and secondary schools. There are some exceptions to this generality with respect to television; some systems do make extensive use of television, and others make moderate use of it.

One wonders why television is so little used, since it is fairly inexpensive and its capabilities are now well demonstrated by numerous experiments. One study of this problem found that teachers and administrators cited reasons such as unsuitable program content, lack of good reception, scheduling problems, unfavorable administrative policies, teacher resistance and lack of funds as primary causes of under utilization. In cases where television is used extensively, these objections have largely been met. Schools which rely heavily on television have provided multi-channel systems, with wide access to quality programming. Under these conditions, teachers have been willing to use television.

Although there are some systems which use television, the over-all level of utilization is low. There are some reasons for this beyond those advanced above--and they speak to very important problems in the public schools.

Television is expensive if it cannot be used to replace teachers. At the present time, nobody has figured out how to integrate television with the custodial function of the school, while saving money at the same time. Television and schools are in competition with one another. Both are media for the delivery of information, and both must compete for limited funds. The use of television within schools can thus be expected to be limited--its most promising applications are outside of schools. Indeed, nearly all of the large-scale operational applications of media described by Schramm et al. (1967: 17-64) meet this problem by side-stepping schools. They note five uses:

1. Upgrading instruction: the purpose of media in this context is to improve the instruction received by students who are already in school. Usually, but not always, the premise is that teachers cannot deliver the quality of instruction available through media. Media then offer a fast and simple means of by-passing an expensive teacher training/re-training program. Examples of this application are found in American Samoa, Niger, Colombia, and the now defunct MPATI program.
2. Training teachers: In this context, media are used to upgrade teacher qualifications without removing them from their jobs. Algeria and the United Nations Relief and Works Agency in Palestine have used this approach.
3. Extend the school: Many countries have areas in which the population density is so low, or travel so difficult, or social conditions so poor, that they extend the school to people who could not otherwise attend by means of media. Probably the best known use in this context takes place in Australia, where an entire school curriculum is offered to students via radio. Each student has a radio teacher, but school conditions must be simulated in his home, for his only contact with the teacher is by radio and correspondence. New Zealand has a similar program; Japan has programs intended to educate working youths; Italy and Peru attempt to reach children who are isolated or who live in areas without schools via television and radio; and Chicago has a junior college which offers a substantial part of the curriculum by television. Britain has just started an ambitious project to offer a university degree via televised programs--thus creating a truly "open" university.

4. Media have also been used to extend basic education in literacy and other fundamentals. Italy, the Ivory Coast, Honduras, and Niger are among countries offering programs of this nature.
5. Last, media can be used for adult education and community development. The educational TV networks of the U.S. are often examples of this, as are the more centrally controlled programs of India, Togo, and Niger. The programs of the less developed countries are often aimed at solving national problems--improvement of farming methods for example.

Each of these uses is characterized by a division of responsibility between the schools and the communications networks.

Another major obstacle to the use of television and other media is the certification function of schools. To get ahead in modern society requires degrees. To get degrees, one must go to school. Thus, if television is to make an impact outside school, educational television systems must find a way to certify their graduates. Steps are being taken in this direction through provision of qualifying examinations for college credit, but many more are needed to reduce the strength of the formal school system in its competition with modern media.

Last, it is necessary to note the lack of coherent learning theory to guide program production for television and other media. In the absence of learning theory there is nothing to guide the production of television programs beyond that available to the classroom teacher. As a result, the overwhelming majority of "educational" television programs have been boring, dull, and of little popular appeal. This has been a strong impediment to the development of educational television, but there is some light at the end of the tunnel provided by such productions as "Sesame Street" which manage to entertain and teach at the same time. (There have been numerous criticisms of "Sesame Street"--most have criticized what is taught or how it is taught. None question the program's ability to teach per se--they just argue that it could be done better.)

D. Prospects for Future Utilization

What are the prospects that CAI and/or ITV will spread to the point where they will make significant demands for communications channels? There are two issues implicit in this question--the first dealing with the spread of the technique, the second with communications requirements associated with the spread.

Communications requirements associated with the spread of ITV and/or CAI are an engineering problem tied to the state of technical development. To the extent that it becomes cheap to produce and distribute ITV and CAI on a local basis, communications requirements will be short range. To the extent that large, centralized distribution and production systems are necessary (as seems to be the case today), the spread of ITV and CAI would require and be enhanced by the availability of low cost long-distance communications links.

With respect to diffusion of television and other media, we might briefly consider the recent increase in the use of media by the medical profession as a means of seeing past the dismal state of affairs in public education. In medicine, prompted by such factors as increased costs and scarcity of personnel, there has been fairly extensive use of technology to increase the power of the doctor.

Sterling and Pollack (1965: 1) note that:

> "Few marriages would appear to have had dimmer prospects of success than the one between the rigorous and highly mathematized applications of computers and the descriptive, empirical, intuitive and often vague practice of medicine. Yet, scarcely a decade after the first tentative explorations of the use of computers in the medical sciences, they have become a vital part of many medical-center and hospital activities."

Sterling and Pollack note three stages in the evolution of technology: exploration of the obvious, discovery of new phenomena, and synthesis of new concepts. Educational applications of CAI and ITV seem to be in the first of these stages at the moment. Basically, few experiments with either device have gone beyond even simple and elementary applications which could be done by humans, were the humans available. There is, however, great potential in these devices to do things which are not possible--in short, it is possible to devise new instructional techniques which take advantage of these media, and to introduce these techniques into education. This has already happened in the case of the textbook, and of some special classroom aides.

Finally, there is the distant possibility that the devices will lead to new synthesis of concepts and ideas in the discipline itself. In medicine, computers have begun to make possible the investigation of complex phenomena which could not be handled by people. In so doing, input if there were to be wide-spread use of the medium. Cable seems better able to meet this need than any system presently available. One of the best uses of cable at present seems to be in Ottawa, where it is used as a means to allow teachers to call-up programs from a central storage facility (McLaughlin, 1970). This on-demand-capability also seems to be a useful characteristic of cable (Barnett and Denzau, 1971).

The development of cheap tape recorders, hand-held television cameras, small television cassettes, and so on, raises the possibility that in the near future, people will be able to produce their own TV program material conveniently and cheaply. The state of development at this time might be compared to that of the world when mass printing devices became cheap for the first time. Clearly, we are upon the fringe of a time when it may be possible for a large number of people to publish via electronic media, just as it is now possible for them to publish in print.

These developments are about to force some fundamental decisions on educators. There is a choice between centrally controlled, mass distribution uses of technology and locally controlled, small distribution. Mass uses are more likely to produce high quality software at acceptable prices, but user controlled operation seems more likely to produce sophistication and understanding of the media themselves.

At the moment, two trends and one fact seem to indicate more reliance on mass distribution centers. The fact is that, given a high quality, convenient system, teachers and students respond enthusiastically to the system and use it. The trends are 1) an increased interest in the education of people who are not presently being reached--either for geographic or social reasons and 2) an increasing interest in individualizing education.

The Coleman report (Coleman _et al._, 1966) turned up information which surprised few--that educational inequality is a serious problem. Such programs as Head Start are indications that the society is concerned to reach groups not being well served by the present system, including inner city black children, Indians, Eskimos, migrant workers, and adults. For most of these groups it would be excessively expensive to train and deploy teachers. TV, and later CAI, however, could be quite effective if a large number of high quality programs could be made available.

The Appalachian TV home-visit mobile-van program is illustrative of what might be done for Eskimos, Indians, and migrant workers. The success of the Chicago Junior College of the Air (Ericksen and Chafsow, 1960) is an indication that large number of people who find it convenient or necessary to stay at home can also be reached and earn college degrees. England has moved into this area on a large scale, and New York State is launching such a program now.

Individualized instruction has been long considered a superior teaching technique, but high costs have been an obstacle to the process. The newer developments in media may allow considerable individualization. CAI, with high quality software and hardware, can,for many purposes, take the place of an instructor. In addition to the drill and practice function and the ability of the machine to select material at the appropriate level of difficulty for an individual student, some CAI programs permit the student to use the computational and logical powers of the computer. Even television, the massest of mass media, can be used in an individualized fashion. This can happen if facilities are available for individual or small groups of students to view programming of their own choice at convenient times.

Another aspect of individualizing has to do with the way classrooms are organized. If some students are sufficiently motivated and curious to do much of their own learning, teachers can spend more time with those children who need special attention. Teachers will act as educational managers and deal with special problems, rather than supply information to the whole class. Media may also play a role in the individualizing of instruction if some students learn better using one device and others learn better with another technique. If ways of identifying this phenomenon are available, the information could be used to select the appropriate medium for the individual. For example, there is evidence that boys perform better with computers than girls, and the "Sesame Street" evaluation indicates a slight, although not consistent, effect in favor of girls. There is also evidence that children of different ethnic backgrounds, of the same social class, display different types of intellectual abilities. Finally, the media may remove a subtle kind of dysfunctional individualization: Education of the Disadvantaged makes the point (p. 127) that teacher attitudes are important in influencing what the child learns, a point verified by Chall (1967). A desirable feature of TV and computers is that they do not place someone into a particular category based on his skin color or appearance. It is interesting to note that the two best performances in a CAI mathematical logic course were turned in by black boys from rural Mississippi. How many teachers would have even tried to teach mathematical logic to such "unlikely" candidates?

In short, the prospects are that the media will be more extensively used. As the costs of delivering large numbers of ITV programs and CAI courses fall, and as the software is developed and improved, these media will have the potential to individualize instruction and reach groups not presently served to an extent never before possible. Surely there are difficulties in their use. But the large number of successful experiments is testimony to their effectiveness.

The above, in general terms, is our belief about the long run prospects. We would also like to be more specific about substitution between teachers and other inputs. Unfortunately, the range of variation one observes in input combinations is quite restricted relative to what is possible. The traditional classroom-teacher-student technology dominates the school, but we are interested in the scope and possibilities for media usage. To do this, we turn to the production function approach, and what it can tell us about educational inputs and outputs.

III. PRODUCTION FUNCTIONS AND EDUCATION

A. The General Production Functions

We believe that many of the questions raised by a discussion of uses for technology in education are usefully viewed as the standard economic problem of allocating scarce resources to achieve given ends. Typically, there are many different ways to produce a given output--for example, using different kinds of machinery, various quantities of labor with different degrees of skill, various sizes and types of buildings, and more or less land. Some of these processes may use more resources than others to produce the same output; such processes are inefficient. But even when inefficient processes are eliminated, there is still a choice between processes. In these cases, it is often useful to conceptualize the problem as choosing that combination of inputs which minimizes the costs of producing a particular output.

Figure 5 illustrates these points. We measure the quantity of two inputs along the coordinate axes; the shaded area represents combinations of inputs that may be used to produce some specified output. Point B represents a process which uses 2-1/2 units of input 2 and 3 units of input 1 to produce the specified output; it is clearly inefficient since it uses the same amount of input 2 as process A, but more of input 1. On the other hand, process C uses more of input 1, but less of input 2 than does A. All points along the lower boundary are efficient. These points make up the production function--the set of minimum inputs needed to produce a given output. This may also be interpreted as the maximum output attainable with a set of inputs.[1]

Choosing whether process A, C, or some other point on the production function is to be used requires information on the relative costs of inputs 1 and 2. Thus, if input 1 is inexpensive compared to input 2, we would expect the minimum cost way of producing the given output to be closer to C than A. More precisely, under the assumption that the unit cost of the inputs is independent of the quantities being purchased, we can represent

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[1] The production function is drawn so as to embody certain assumptions about technology which are discussed in more detail in a number of references.

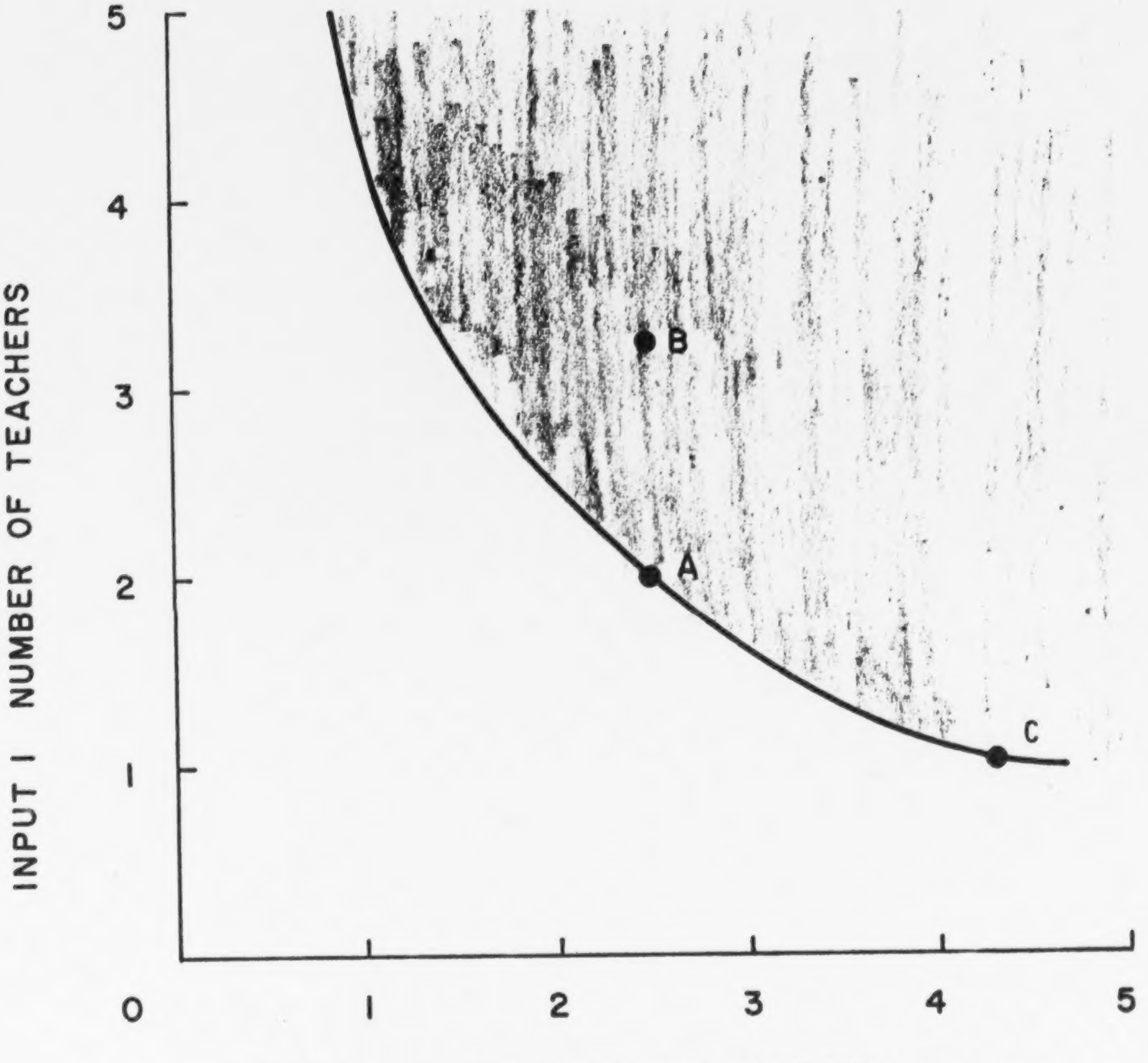

FIGURE 5 HYPOTHETICAL PRODUCTION FUNCTION FOR FIFTH GRADE READING SKILLS

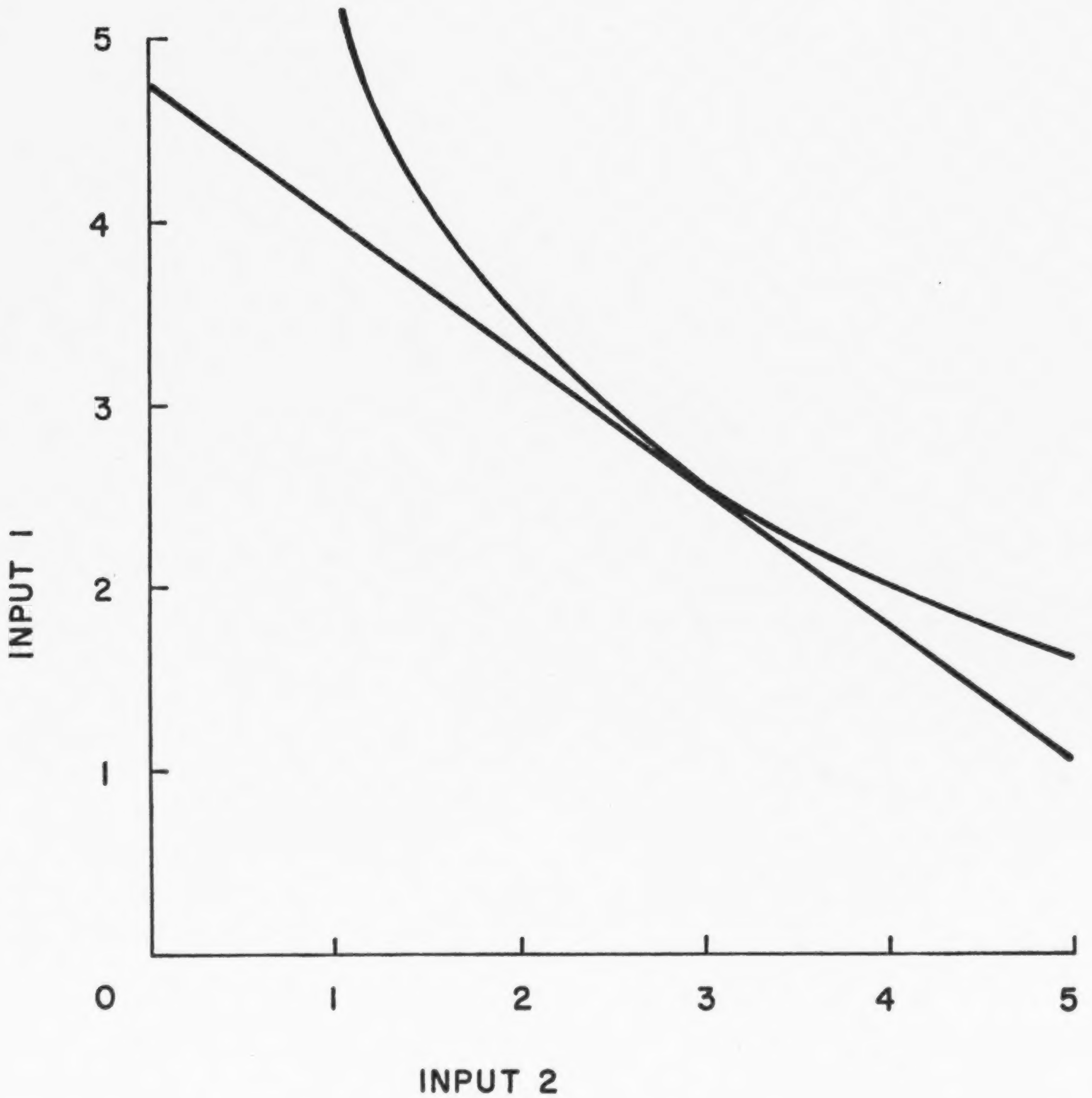

FIGURE 6 ILLUSTRATING THE USE OF PRODUCTION FUNCTIONS IN COST MINIMIZATION

the relative costs by a straight line on our production diagram. Parallel shifts of the line in the northeast direction represent a greater total expenditure at the same relative input prices. Thus, to minimize costs to produce a given output, we must keep the expenditure curve as southwest as possible, but still using sufficient inputs to produce what is desired. Graphically, the optimal inputs are those given by the point at which the expenditure line is tangent to the production function. (Figure 6)

In the production function context the inputs required to produce a given output depend on relative prices. That is why, in our opinion, it is misleading to seek future "requirements" for educational technology in the absence of data about relative costs of labor and technology for meeting specified objectives. At the moment, most educational objectives defy specification in terms amenable to production functions analysis. We need to know the objectives of the educational system (outputs) and some alternative ways of reaching those objectives (production functions). Then we could begin to design alternative systems of providing inputs and to estimate the costs of those systems.

Educators should be expected to provide information about the objectives of education and to conduct experiments enriching our knowledge of the learning process, but they are not the people who should be expected to outline the configuration of systems to deliver inputs to students and teachers.

We next turn to a consideration of the problems in specifying precise production functions--educational and other--and by an attempt to set out what is known about educational production functions at a level of analysis (aggregation) which might offer practical guidance to the use of technology in education.

B. Problems in Specifying Production Functions

Having seen, in general terms, the nature of the inputs and outputs of American education, let us approach the question of estimating production functions for education. Our concern will be primarily with the output we characterized as the transmission of knowledge, skills, etc.

Although texts in microeconomics treat the production function as though it were a tool routinely used by businessmen for choosing the least cost method of producing a given output, very few production functions have been estimated for this purpose. In most cases, estimated production functions have made use of observations at a fairly high level of aggregation; for example, much of the early work was at the level of GNP as the output, and the inputs were total man hours and capital equipment. Clearly, this does not tell anyone how much capital equipment and labor to use, nor does it necessarily indicate that government policy should stimulate capital formation, since particular plants and machinery must be constructed, not abstract capital.

Many industry production functions have also been estimated, but these have often used value added (industry sales minus purchased materials) as outputs, and man hours and dollar value of capital as inputs. For such industries--agriculture, textiles, etc.--this is still too high a level of aggregation to tell decision-makers how to combine inputs. Farmers produce particular crops or animals with particular kinds of machinery and other inputs; and textile manufacturers produce different kinds of outputs. Of course, it was not the intent of the researchers to derive operational production functions; their main concern has been to use fairly aggregate production functions in order to study the impact of technological change on general issues such as income distribution (Walters, 1963), and natural resource scarcity (Barnett and Morse, 1963).

There are two major exceptions to this generalization. For many years agricultural production functions have been estimated with the object of helping farmers to increase their profits by selecting the correct types and amounts of fertilizer and other inputs. It is instructive to note that these have been estimated at low levels of aggreation--individual crops, kind of fertilizer--using experimental techniques (Heady and Dillon, 1961).

The second major area in which production functions have been estimated and applied is for the analysis of military decisions. The work of Hitch and McKean summarizes the advantages and difficulties with the approach (Hitch and McKean, 1961).

For the purpose of estimating educational requirements for technology, we need to have production functions estimated at levels of aggregation low enough to tell us about combinations of inputs--teacher time, TV, CAI--which could be used to bring the student up to a particular reading level, or some other achievement. Production functions at this level of aggregation will be called "operational."

Perhaps the ideal way to determine production function is to start from the underlying physical, chemical, psychological, or other laws which relate inputs to outputs. Examples of this approach may be found in several places. One such study considered electricity transmission and derived the relationship

$$X_2(x_1-y)-K_y^2 = 0,$$

where y = power output of transmission line,

x = power input of generating source

X_2 is a function of cable length and cross-sectional area and density of the conductive material, and

K is a function of the power factor, length, resistivity, and the required voltage. (Smith, 1961, pp. 24-30.)

In most cases the physical processes are so complex and there are so many uncontrolled variables that it is not possible to derive production functions from more fundamental relationships. This is the case in agriculture, the industry for which most successful operational production functions have been estimated. If it is not practical to estimate engineering production functions, one may turn to statistical methods to obtain the relationship between inputs and outputs. There are two basic types of statistical production functions. One makes use of data generated by controlled experimentation, and the other utilizes data from the actual experience of individual farms or manufacturing plants.

There are, of course, great advantages to the experimental approach. The inputs can be carefully controlled to explore the production relationships over a wide range; randomization may be practiced so that those inputs which are not of interest may be ignored; and replication may be practiced to obtain estimates of sampling variance. Much of the success of agricultural production functions is due to the ability to conduct experiments with seed, fertilizer, and other inputs under carefully controlled conditions.

When experimental techniques cannot be used, much can be learned if appropriate data are available. An excellent example is the estimation of a production function in thermo electric power production. For this application there is a well defined output measure--kilowatt hours--and fairly disaggregative data are available on labor and capital equipment inputs. Approximations had to be made to determine the utilization of each type of capital--which could have been controlled if experiments could have been run--but the study estimates what appears to be a reasonable production function (Galatin, 1968).

Another study performed at a low level of aggregation was performed to estimate production functions for metal machinery. "Pieces per daily 8-hour shift" was the measure of output, but since the pieces are not uniform, characteristics of the piece (geometrical, size, required tolerance, and size of lot) were included as input variables along with capital investments and number of men per 8-hour shift (Kurz and Manne, 1963).

To summarize the discussion thus far, the data for most production functions estimated by economists have arisen from unplanned experiments. Most have been estimated on observations at a level of aggregation higher than would be useful for allocative decisions at the decision-makers level. In agriculture, where outputs are well-defined and experimental techniques are available, operational production functions have been estimated.

Before turning to educational production functions, another aspect of measuring outputs should be mentioned. It may have been noticed that the outputs used have been one-dimensional in nature (kilowatt hours of electricity) or weighed aggregates of one-dimensional values (the sales portion of value added is price times quantity of various outputs summed over the number of quantities). But it may be objected that in many cases output cannot be described in one dimension, and there is no natural weighting scale to aggregate the individual quantities. If in these cases we focus on one particular output, the other effects caused by the production process are called "side effects". These side effects, of course, may be extremely important, perhaps as important as the output being measured. For example, the economists' emphasis on GNP as a measure of output places environmental pollution in the category of side effects.

If the process being investigated is at a fairly low level of aggregation, side effects are not likely to be overwhelming; they should be watched for, of course. On the other hand, the possible existence of undesirable side effects should not necessarily deter experimentation; rather, the experiment should be designed so as to allow the possibility of recognizing them.

For example, the metal machinery study mentioned above treated as output the number of pieces produced. It did not attempt to measure whether the workers were happy. For some purposes the latter information is very important. Since the data were derived from an ongoing production process, one assumes that the workers unhappiness was within acceptable bounds. If one were able to run a planned experiment in the plant, however, one might have to take care to see that the experimental conditions did not cause difficulties with worker morale that would be counter-productive.

One final related point on outputs. Economic theory is ultimately concerned with what we may loosely call economic welfare, which is not observable. Often we turn to numerical quantities as approximation. For example, we measure the number of aspirin produced, not headache-free hours or better still, the subjective value of headache-free hours. Economists have not been reluctant to make this kind of approximation. It is difficult to decide, on balance, whether the mistakes have been more serious than the benefits. However, as noted above, the problems are less severe at low levels of aggregation in controlled situations, and the experimenter should be alert to the possibility of side effects.

This does not mean that experiments should not be undertaken. Educators are prone to argue that since educational outputs are so complex and so difficult to measure that one cannot conduct experiments without doing great harm to the educational process. This is to apply a double standard to research, since researchers must show a) that their projects have a positive effect in a desired output and b) that they have no undesirable side effects. Educators apply a quite different standard to their own operations--they avoid estimates of positive effects by stating that outputs are too complex to be measured (unless they have to decide whether or not a child is to pass or fail), and they do not admit the possibility of undesirable side effects.

C. Education Production Functions Concepts

It has frequently been remarked that no one actually estimates production functions on the micro level because the engineers think the economists are doing it, and the economists think it is an engineer's job. That is, economists view production functions as technical relationships and assume that it is not extremely difficult to select a reasonable set of production methods from the large number of possible techniques. Engineers see production processes as very complex; they see a large number of choices to be made, including not only the machines to be used, but also the way they will be arranged in the plant. In addition, they realize that machines ordinarily come in fixed capacities and do not permit the continuous kind of variations assumed by the production function described above.

In any event, as we have seen, agriculture and the military are the only examples for which operational production functions have been derived and utilized to any significant extent. Is it possible to estimate this type of production function for education, and would it be useful to do so? We believe that it is possible, and would be worthwhile, particularly as a way of organizing research.

To estimate educational production functions, one must face the same problems that are encountered in estimating any type of production function. It has often been argued that these difficulties are particularly severe in education. Specifically, it has been pointed out that outputs are not well-defined, that there are important side effects, that there is no generally accepted theory of learning, and that school administrators are not necessarily minimizing costs for a given output or maximizing output from given costs. It is our belief that many of these problems may be avoided by working at relatively low levels of aggregation. Let us consider each of these in turn, then discuss the findings of a large number of educational production functions at high levels of aggregation, and finally turn to what evidence we have on operational production functions.

1. Outputs and Side Effects

As we have seen, measuring output is generally difficult in economics, but that in a well-defined situation, such as production of a particular crop, it is possible to make progress. Similarly, if the output measure is a vague notion, such as an "educated child", estimating production functions would be worthless. If, on the other hand, we care about whether a child can learn to read a some minimum level, and may experiment with various combinations of inputs (people, facilities, techniques) to find efficient ways of doing the job, the production function approach will be useful. We may find out that different children learn somewhat differently; identifying this situation would be an important research finding (cf. Snow and Salomon, 1968).

2. Optimizing Behavior

If school administrators are not attempting to minimize costs, or maximize output, then observed data may not properly describe a production function. Even if we assume that all businessmen are profit maximizers, we still have the difficulty that not all are equally skillful. Most production functions (or estimates of cost curves) have used statistical techniques which permit observations to do better than the production function, obtaining what we might call an "output" function. This yields the average output to be expected from a particular input combination. There will always be teachers who do better than the average teacher, even if only with a particular class. In any event, there will be sufficient random variation that it is probably neither feasible nor desirable to estimate the production function. We do need to know what the effect is on the average output of a small change in the inputs. It should be possible to do this from a series of well-designed experiments, and there should be a continual effort to identify institutions performing exceptionally well. Hopefully, it will be easier in education than in business to pass on particularly effective techniques to "competitors".

3. Relevant Learning Theory

It is probably accurate to say that there is no generally accepted learning theory that can be used for constructing engineering-type production functions. A cursory examination of psychological learning theory reveals an emphasis on more privitive types of learning behavior than what is involved, for example, in learning to read. However, as we have seen, statistical type production functions may be constructed and experiments can be run, a possibility not available in most economic applications.

This absence does not mean that we are operating without knowledge. A large body of information already exists, gleaned from practical classroom experience, psychological and sociological theory, controlled experiments, and introspection. While this information is of varying quality, it is clear that we are not operating in a vacuum. Even if much of the received wisdom is incorrect, we have a place to start.

As examples, we consider two approaches to learning theory. Bloom (1968) discusses learning from the student's viewpoint; and Bretz (1971) considers the question from characteristics of the subject matter. While they do not provide formal learning theories, they provide taxonomies and guides for research.

Bloom (1968) has pointed out five variables required for mastery of subject matter content, and suggested a strategy for applying the variables so that students can actually master subject matter.

1. Aptitude for particular kinds of learning. Bloom bases this on Carroll's (1963) notion of aptitude as the time required to learn something. The assumption in using the term this way is that almost any student can master anything, given enough time. Bloom suggests that about 90% of the student body in an average school should be able to master subjects up to a "high level of mastery", given enough time and appropriate help.
2. Quality of instruction: Bloom (1968) and Carroll (1963) both define quality of instruction in terms of its adequacy for the individual learner (as opposed to the more usual definition in terms of its appropriateness for a class or group of learners). Bloom's point is that quality of instruction, which is normally assessed in terms of group achievement, has to be assessed in terms of individual achievement if schools are to teach mastery of a subject.
3. Ability to understand instruction: Bloom defines this variable as the ability of the learner to understand instruction, the nature of the task he is to learn and the procedures he is to follow in learning the task. Bloom notes that most instruction

in schools is highly verbal, and that there is high correlation between verbal ability and success in school. This, he suggests, indicates that school men need to seek out a wider variety of instructional modes to present tasks to be mastered. He suggests group study, tutorial help, textbooks, audio-visual instruction, workbooks, programmed instruction, and games. The point of these alternatives is to provide a wider range of means by which students may be able to master a subject.

4. Perseverance: is defined by Carroll as the amount of time the learner is willing to spend in learning. So defined, it looks much like the more traditional motivation. Bloom points out that students approach subjects with great differences in perseverance. He also points out that one way to increase perseverance is to provide frequent feedback and to make learning as easy as possible. There is, he says, little reason to make learning so difficult that only a small proportion of the students can persevere to mastery.
5. Time allowed for learning: is a key variable in Bloom's conception. He wants each student to have enough time to master a subject. Although he does not mention it, we assume that he would also feel that students should not be required to spend more time on a task than is required to master it. In general, it would seem that schools frustrate both the bright and the slow students by ignoring the importance of the time variable.

Bloom suggests several important preconditions for mastery of a subject or skill: there must be specification of objectives and content of the curriculum; standards of mastery and excellence should be absolute, that is, they should not be dependent upon a student's position relative to others in the class; there must be a distinction drawn between the teaching - learning process and student evaluation; and tests used for student evaluation should be separated from those used for evaluating the learning process.

Bretz (1971) considers the uses of communication in the learning system. Several of these uses suggest an implicit learning theory:

1. Providing the learner with knowledge of his learning objectives.
2. Motivating the learner.

3. Presenting information.
4. Stimulating discussion.
5. Conducting drill and practice.
6. Reinforcing learning.
7. Providing a learner/simulator interface.
8. Evaluating learner progress and program effectiveness.

He then sets up a framework to determine the types of media needed to present particular subject matter. For example, an affirmative answer to any of the following, or similar questions, would suggest that some type of visual medium is necessary.

1. Is visual recognition and identification of objects, signs, or symbols other than language symbols an objective of the lesson or required for job performance?
2. Is the recognition or recall of a procedure, the physical actions or positions of which are unfamiliar to the learner, one of the objectives of the lesson?
3. Is the understanding of two-dimensional physical or spatial relationships an objective?
4. Is the recall or recognition of the three-dimensional structure of some physical system or object required?

Similar questions are suggested to determine requirements for audio and full motion. These "theories", while crude, exemplify the sort of work which must be done if educational production functions are to be fully developed.

D. Education Production Functions--Evidence

One of the key questions in assessing the school system concerns its ability to distribute knowledge. We want to know who is getting what kind of education, and we also want to know who is not getting educated. One of the first major attempts to discover something about the distribution of education in the United States was a project culminating in the Coleman report (Coleman et al., 1966). The report served as the prototype for a large volume of research into the relationships between a child's performance on a standardized examination and measures of his ability, home and school environment, and other variables. Economists experimenting with the same type of formulation explicitly used a production function framework for presenting and interpreting the results. Selected studies of this type are summarized in the Appendix, and are briefly discussed below.

1. Some Problems in Obtaining Evidence

"Equality of Educational Opportunity" or the Coleman report points out (p. 286) that school to school variations in achievement tests are much smaller than individual variations within the school, at all grade levels, for all racial and ethnic groups. This presents the problem that resources may be unequally distributed within the school and may have an effect not picked up by regressions in which the input variables are on the level of schools, but the output is individual student performance. In other words, the Report does not yield an operational production function as we have defined it because the input data were not on the same level of aggregation as the output data. The Report's inference is that "...variations in school quality are not highly related to variations in achievement of pupils." But if there is tracking, or other ways of discriminating, the evidence is inconclusive. Moreover, Coleman's measures of facilities are not useful for our purpose. They include library volumes per student, science laboratory facilities, and number of extra curricular activities. As the Report states:

> The effect of school factors in producing variations within a school cannot be assessed in this study, because data were not gathered on the differential experiences within school, such as the particular set of teachers in a school who had taught each student (except for those experiences that are highly dependent on a student's achievement itself; for example, the number of mathematics courses he has taken).
>
> Thus the effects of school factors studied in this survey must manifest themselves in school-to-school achievement. The task becomes one of separating the three possible sources of such variation, so that some idea can be gained of the magnitude of school effects.

Mood (1970),in a thoughtful review, discusses the problems of interpretation which arise because we find that there is a relation between socioeconomic status and characteristics of the schools attended. For example, wealthy white students tend to go to schools with better library facilities and better teachers than do poor black children. This makes it difficult to untangle the school effects from the socioeconomic background effects.[1]

With this in mind, let us examine what the researchers have found out about the effects of various inputs on measure of output. The input variables have been placed into the following categories:

1. Socio-economic status
2. Pupil and peer characteristics
3. School characteristics
4. Teacher characteristics

In general, the studies confirm the Coleman report findings. Variables representing socio-economic status continue to have strong impacts on achievement. Such measures of teacher quality as verbal ability, education, experience, showed significant impacts in a number of studies. In addition, significant relationships for variables representing school facilities and curriculum appear in several studies.

The level of aggregation that concerns us must be low enough to permit us to answer (or at least, ask) the question: Could ITV or CAI be used to complement the existing educational system? Thus expenditure per pupil would not be useful because it does not tell us anything about how to spend the money. On the other hand, the teacher-student ratio is at the appropriate level. Further, we are interested in impacts on individual students, rather than on averages by school or school district, because of the substantial variation of achievement within school and school district and the possibly unequal treatment afforded individual students within the same school or district.

By this test, many of the studies described in the Appendix do not provide useful information for us, beyond confirming the general importance of socio-economic status and other of the Coleman Report findings. The studies, in general, do not relate individual student achievement in a fairly narrowly defined subject area to inputs affecting the individual student, controlling for extraneous variables.

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[1] Bowles and Levin (1968) make similar points about the level of aggregation and also point out possible biases due to high nonresponse rates and to the use of academic-type testing for all students.

Although to our knowledge, no one has set about to estimate production functions at the level we need, research directed toward other ends is enlightening. For example, the vast amount of research which attempted to learn whether TV or a face-to-face lecture were more effective generated much of the information needed for production function estimation. The best of these studies, summarized in Dubin and Hedley (1969), were concerned with individual student performance in particular courses. They frequently controlled for student ability in an attempt to isolate the effects of the method used to deliver the lecture. Moreover, several of these research projects went beyond the learning of the particular subject matter to determine whether TV had differentially affected the student's attitudes toward a number of things--that is, an attempt to discover side effects (Carpenter and Greenhil, 1958; Salomon, 1970).

The evidence from these and studies done at the elementary and secondary level is that TV does just as good a job as face-to-face instruction. However, for production function purposes, our interest is not so much in whether one factor can replace the other, but how the factors can be used most effectively together. Doing without one or the other input entirely is an extreme case; we also require information about what happens when the inputs are used together. That is, the design of the typical study performed to detect the differential effects of TV versus face-to-face concentrated on the coordinate axes of the production diagram, and concluded that points A and B, in Figure 7, yielded the same output.

Since the economist's usual assumption is that one input will rarely be used to the exclusion of all others, it is of interest to explore combinations of the two, when the two are combined as effectively as possible. However, an experimental design which compares the average achievement of TV-taught students and face-to-face taught students does not generate sufficient information. Needed is a series of studies which deliberately vary the TV and teacher input, for example, to explore the production set. It is interesting to note that early agricultural studies also were of the "evaluative" variety; they compared yields with and without application of a specific amount of fertilizer. It was only later that attempts were made to explore the production function; the statistical tools shifted from analysis of variance to regression.

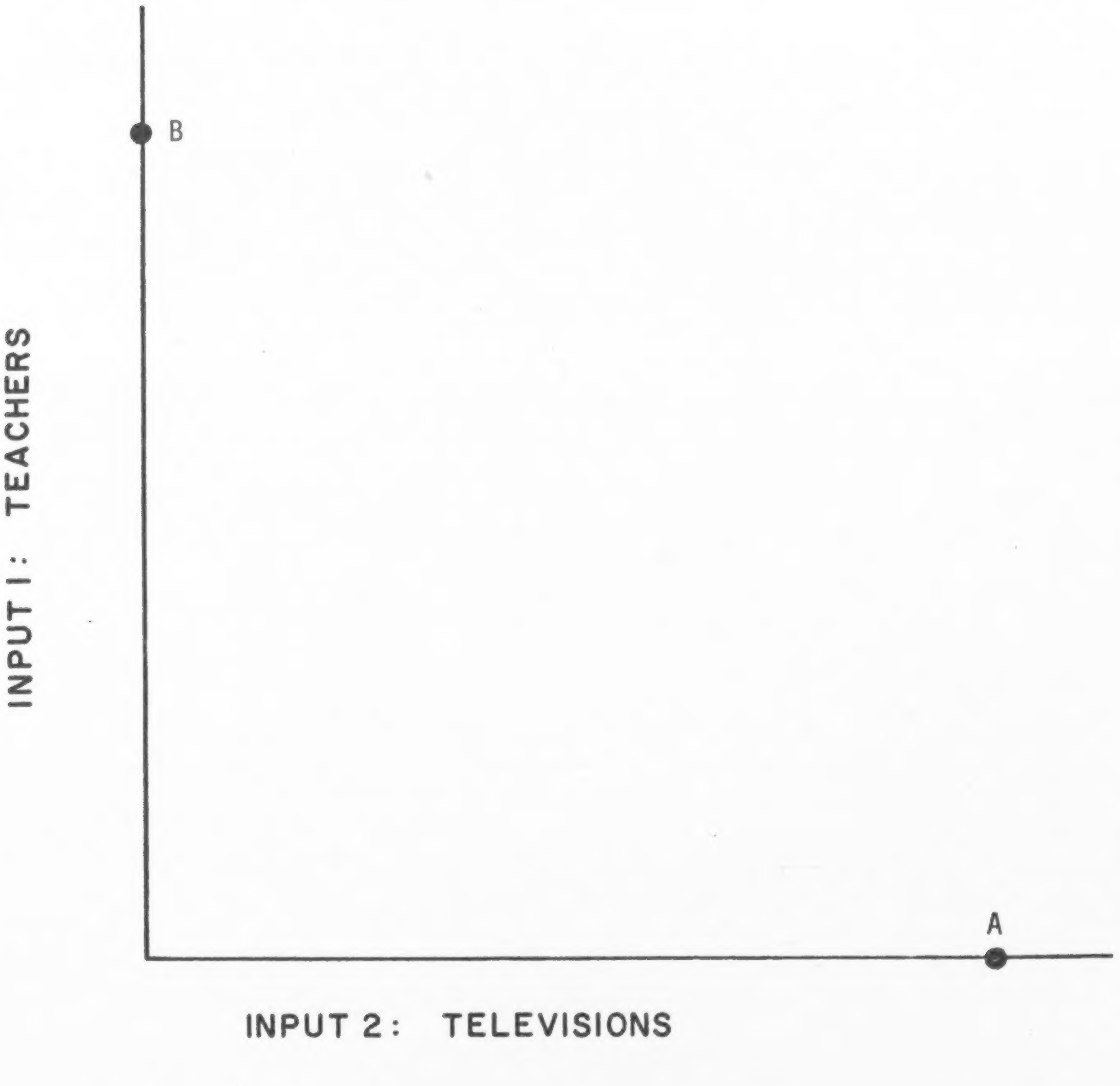
B
INPUT I: TEACHERS
A
INPUT 2: TELEVISIONS

FIGURE 7 ILLUSTRATING SUBSTITUTION OF T.V. FOR TEACHERS

An example of an attempt to combine live teachers and TV in a way which takes advantage of the best characteristics of each is reported by Skinner (1968). In his experiment, a fifth grade class was exposed to a TV presentation designed to stimulate curiosity and interest before the information is presented by the classroom teacher. Although it was a small-scale study, and not carefully controlled, it illustrates the kind of experimentation and development which will be necessary to explore the production set.

2. Combinations of Inputs

Let us now consider the methodology and findings of a number of large scale studies which, more or less, attempted to consider the effects of various combinations of inputs.

a. Denver-Stanford Spanish Course

Fifth and sixth grade children in the Denver public schools were exposed to Spanish instruction starting in the 1960-61 school year. Each child viewed a 15-minute televised lesson on Monday, Wednesday and Friday. During the second semester, the children were divided up into groups, each of which received additional treatment, as noted in Table IV. (The second column refers to the treatment received during the first semester.)

The basic experimental design and average test scores are displayed in Table V, where 1 indicates presence of treatment, and 0 indicates absence. (p. 22.)

More details about the study and results may be found in the Denver-Stanford reports. It is interesting to note, for example, that among students who received a second, night, viewing of the program, parent help was able to replace classroom practice. The operation of the experiment is evidence that large scale studies of this type are feasible; and the kind of information which results is of direct use to decision-makers.

The "Early Childhood Education Program" of the Appalachia Educational Laboratory is similar to the Denver Spanish course in its attempt to combine an interesting input mix. It uses daily TV programs, weekly units, and group work in a mobile van to reach 3, 4, and 5 year olds in rural West

Table IV

GROUPS AND NUMBERS OF SUBJECTS IN THE ANALYSIS OF THE SECOND SEMESTER FINAL

Group Number	(First Semester Identification)	Practice Followed: TV Viewing in the Classroom Plus	Number of Subjects
1	(2)	A Second TV Viewing at Night	91
2	(3)	Dialogue Practice in the Classroom	166
3	(4)	Structure Practice in the Classroom	210
4	(5)	Eclectic Practice in the Classroom	161
5	(6)	A Second TV Viewing at Night and Parent Help	116
6	(2-3)	A Second TV Viewing at Night plus Dialogue Practice in the Classroom	272
7	(2-4)	A Second TV Viewing at Night plus Structure Practice in the Classroom	274
8	(2-5)	A Second TV Viewing at Night plus Eclectic Practice in the Classroom	291
9	(6-3)	A Second TV Viewing at Night and Parent Help plus Dialogue Practice in the Classroom	138
10	(6-4)	A Second TV Viewing at Night and Parent Help plus Structure Practice in the Classroom	149
11	(6-5)	A Second TV Viewing at Night and Parent Help plus Eclectic Practice in the Classroom	134
		TOTAL	2,002

(From Hayman and Johnson, 1962, p. 20.)

TABLE V

DESIGN OF THE DENVER-STANFORD PROJECT: TREATMENTS

Group No.	Average Test Score*	Classroom TV Viewing	Night TV Viewing	Classroom Practice			Parents Help	Number of Subjects
				Dialogue	Structure	Eclectic		
1	27.9	1	1	0	0	0	0	91
2	34.1	1	0	1	0	0	0	166
3	35.5	1	0	0	1	0	0	210
4	36.1	1	0	0	0	1	0	161
5	34.8	1	1	0	0	0	1	116
6	35.1	1	1	1	0	0	0	272
7	35.6	1	1	0	1	0	0	274
8	35.6	1	1	0	0	1	0	291
9	37.1	1	1	1	0	0	1	138
10	36.7	1	1	0	1	0	1	149
11	36.6	1	1	0	0	1	1	134

*a test of Spanish listening comprehension.

(From Hayman and Johnson, 1962, p. 20-22.)

Virginia. An evaluation of the entire three year experiment will be available shortly.[1]

b. Sesame Street Evaluation

An attempt to evaluate the impact of the Sesame Street programs on 3 to 5 year olds during the 1968-69 school year turned up information that could be used in production function estimation (Ball and Bogatz, 1970). For each child, the following information was obtained:

1. Pre- and post-test scores on a battery of tests
2. Extent of viewing (4 categories, varying from never or once a week to more than five times a week)
3. Whether or not the child is disadvantaged
4. Whether viewed in school or at home
5. Whether or not viewing was encouraged
6. Age

Exact definitions of the variables and details for scores on the battery of tests may be found in the complete report. Table VI deals only with the "grand total" score and illustrates ways in which greater viewing of Sesame Street could offset some individual characteristics. Two illustrative production diagrams appear as Figures 8 and 9. The points generate a plausible diagram. Figure 9, for example, indicates that four year olds in viewing quartiles Q_2, Q_3, and Q_4 do about as well as five year olds in Q_1, Q_2, and Q_3, respectively. (In each case, the four year olds' pretest scores were below the five year olds.)

We believe that more sophisticated analysis of this type could be done with the individual child data. Much information has been collected for each child, and the large number of observations would permit a great deal of experimentation with functional form and interactions.

c. Stanford CAI for Disadvantaged Children

Probably the best documented and evaluated CAI experiments for elementary schools has been directed from Stanford. Some interesting experiments have recently been reported for the arithmetic program,

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[1] The Initial Evaluation Report: Early Childhood Education Program, 1969-1970 Field Test, Division of Research and Evaluation, Appalachia Educational Laboratory, Charleston, West Virginia, May 1971, is more concerned with description than analysis.

Table VI

Sesame Street Evaluation Results

	Q_1		Q_2		Q_3		Q_4	
	pretest	posttest	pretest	posttest	pretest	posttest	pretest	posttest
Disadvantaged	76	95	84	113	88	126	98	145
Advantaged	95	122	102	141	113	153	111	156
Disadvantaged								
3 year olds	61	73	62	93	65	102	76	133
4 year olds	75	93	84	115	87	125	94	143
5 year olds	89	112	101	128	104	143	121	158

Source: Samuel Ball and Gerry Ann Bogatz, The First Year of Sesame Street: An Evaluation. Educational Testing Service, Princeton: October 1970.

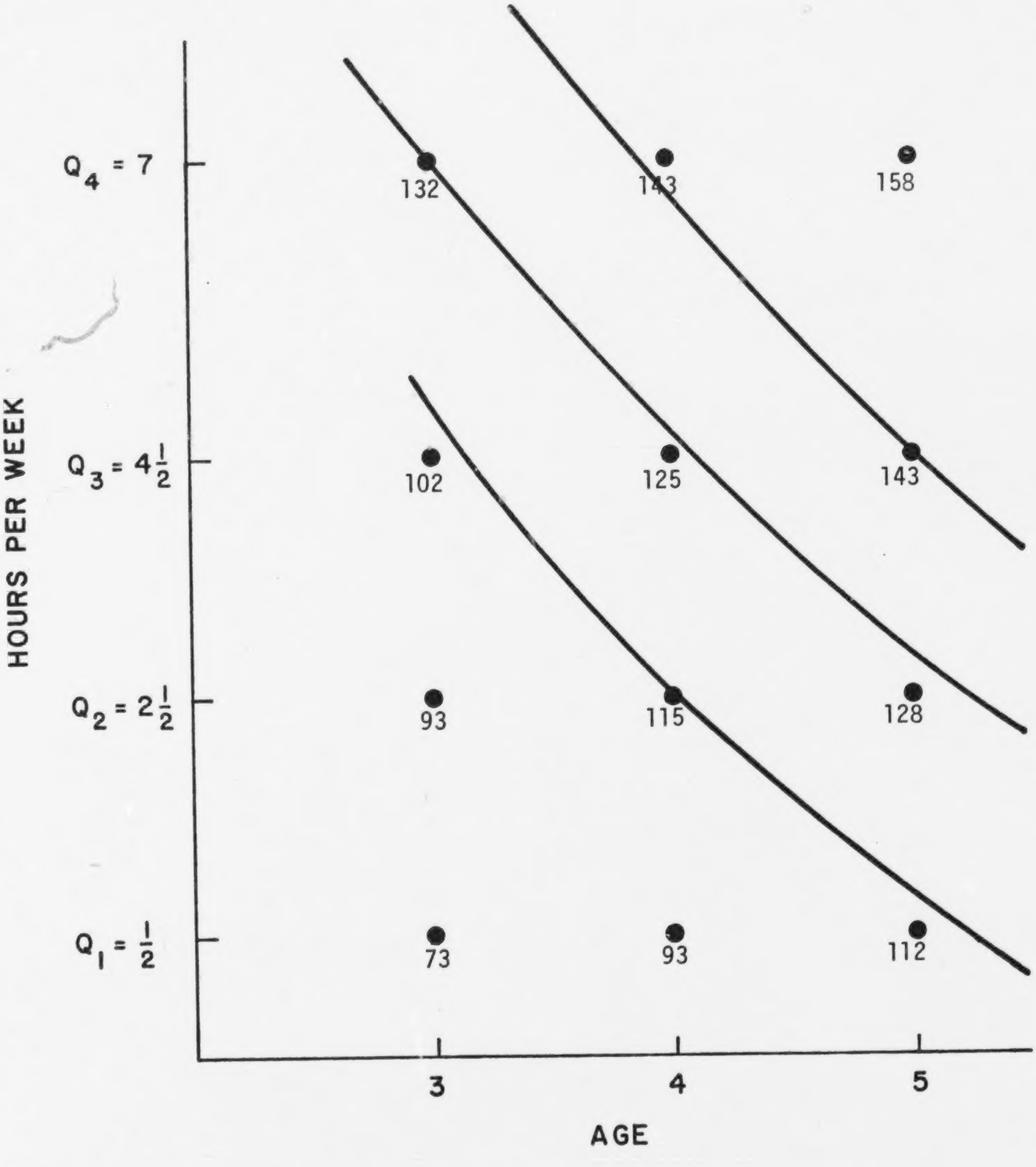
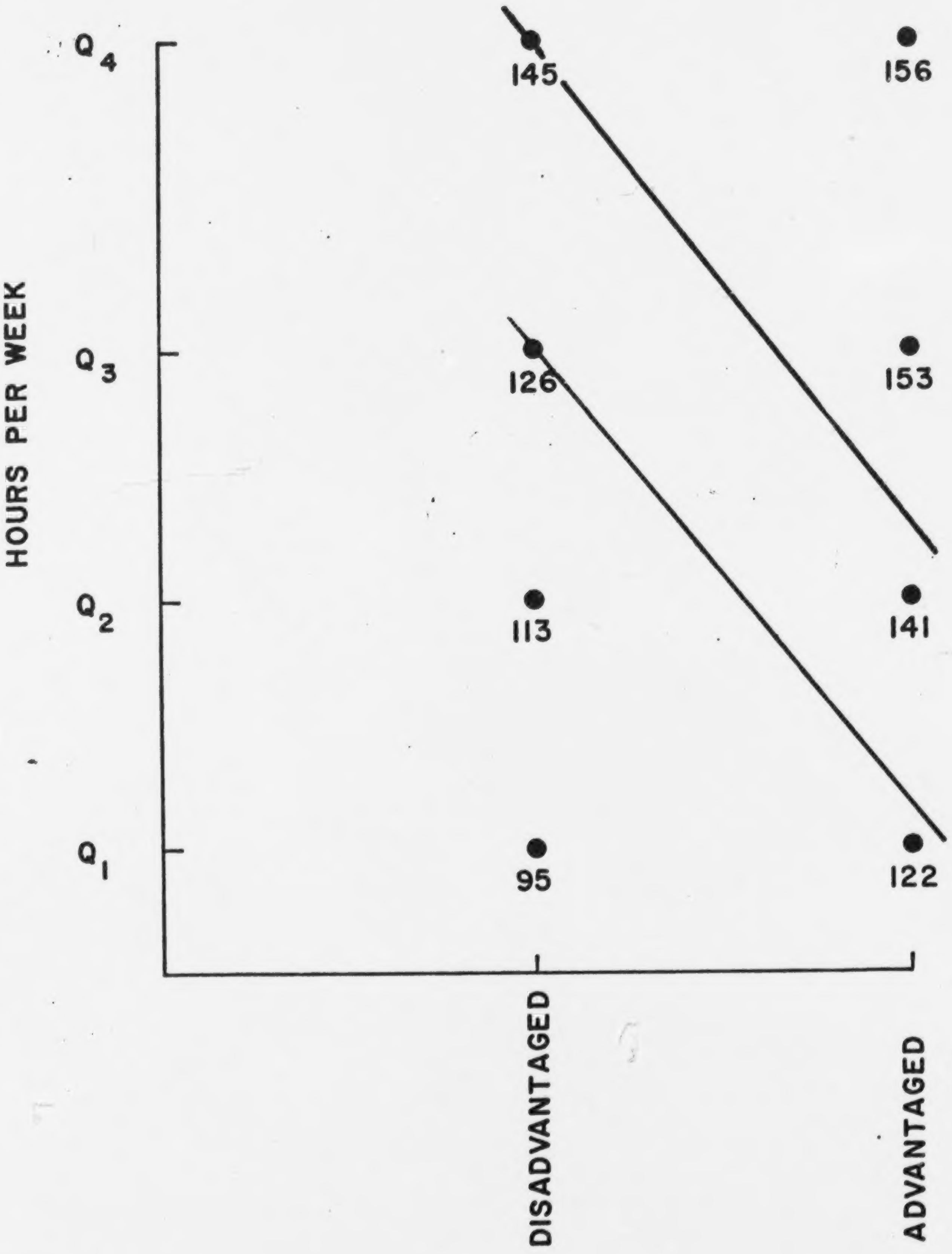


FIGURE 8 ALL DISADVANTAGED CHILDREN POST TEST SCORES

FIGURE 9 ALL CHILDREN POST TEST SCORES



SOURCE: TABLES 12a, 12b, 12c, 11, AND 24 administered to students in grades 1 - 6. It was found that CAI students in rural areas of Mississippi performed statistically better than non-CAI students from the same area for all grade levels tested. The performance measure used was taken from the Stanford Achievement Tests. Results with the CAI course, when the students were from middle-class, suburban California schools, were less conclusive. Although the CAI students in grades 2, 3, and 5 performed statistically better than the non-CAI students, this was not the case in the remaining grades.

Moreover, it was found that the distribution of grades was more equal for the CAI students than for the others. This is attributed to the possibility that individual students may get "lost" in a classroom, but the one-to-one relationship with a computer makes this less likely.

An attempt was made to determine the determinants of achievement gain using multiple regression. In this case, the CAI students received instruction in computer programming and the achievement test was the sum of the computation and the application sections of the SAT. The CAI effect is positive, but not statistically significant. However, only 58 observations were available for testing (Jamison et al., 1971).

These results should be interpreted as tentative, since the experiments did not always run smoothly and because the software needs further development. Nevertheless, they are suggestive for two reasons: First, the study provides evidence that constructing production functions using relevant measure of output and input, on the level of individual students, is feasible. Second, disadvantaged children are apparently aided to a greater extent than the advantaged children. The reason may be that the quality of teaching received by the disadvantaged child is not as high as that received by the advantaged child, or that the type of thinking necessary to perform well on the computer is better developed in the middle class students to start with. In any event, if society places "equality of education" high on its agenda for the near future, techniques which can partially bypass the less prepared teacher and which require logical precision, as does the computer, may be necessary.

Similar results are reported in another experiment, which might be mentioned briefly.

> An instructor taught a mathematics course to three classes in three different ways. The first class received conventional instruction--lectures, class discussion, and typical pen and

paper homework assignments. The remaining two groups learned "flow-charting," a method of breaking down the "chain of thought" used by a computer and expressing it in a diagram. One of these two groups was taken a step farther and learned computer programming and did their homework on the computer.

Each group was given a test in abstract reasoning and general scholastic aptitude at the beginning and end of the school year. The results indicated that students who learned computer programming increased their score on the abstract reasoning test by an average 17.2 percent, while the students who learned only the flow-charting increased their scores by an average 9.7 percent. The control group, taught in the traditional method increased its score by an average 4.6 percent.

The trend was maintained in the results of the scholastic aptitude test, with the computer-trained students increasing their scores by an average 7.5 percent, compared with 5.1 percent by the flow-chart-trained group and 2.9 percent by the control group. (These figures are not to be taken as proof of the computer's effectiveness, but indicative of an area worthy of further investigation.)

A second study, made in Altoona, Pennsylvania, indicated that slow learners in mathematics improved their scholastic aptitude test scores fourfold over a control group by the using of the school's computer time-sharing terminal.[1]

d. Kiesling: Compensatory Education

The Kiesling (1971) study attempts to measure classroom activities of students enrolled in California Title I projects during 1969-70. The study was confined to projects which emphasized improved reading and which used the Stanford Reading Test as a measure of performance. However, the measures of performance and input variables relate to averages of programs, rather than individual students. Thus, the study is not quite on the desired level of aggregation, but is interesting for its attempt to obtain a large variety of input variables. (See Table VII). In about half of the 42 schools, the input and output data were associated with the particular program. For the rest, the input data were gathered over a larger universe.

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[1] "Five Massachusetts Schools Pioneer Computer Education", Educational Media, Vol. L, No. 10 (March 1970). The experiment was not sufficiently detailed in the article to evaluate its findings.

Table VII

Complete List of Variables Used

Dependent Variable
  Average gain in reading score per month of instruction

Beginning Performance Level
  Reading score, beginning of program

Program Length
  Program Length

Program Breadth in School (Probably also a socio-economic and urbaness variable).
  Percent of children in school in Title I program

Program Longitudinality
  Percent of children getting treatment the previous year

Socio-economic characteristics
  Percent of children in school attendance area on AFDC
  Percent of program children in a racial or ethnic minority
  Percent of program children with Spanish surnames
  Percent of program children black
  Percent of beginning program children who moved

Intensity of Instruction
  Individual equivalent minutes of instruction per week

Instruction Characteristics
  Percent of instruction given by trained reading specialist
  Percent of instruction given by para-professionals
  Percent of instruction given by classroom teachers
  Percent of instruction given in the regular classroom

Leadership-Teamwork Characteristics
  Hours per week of planning
  Hours per month in-service training
  Percent of key people routinely informed of prescriptions
  Percent of key people present in planning meetings
  Teamwork index (Average of previous two variables)

(From Kiesling, 1971, p. 26.)

An interesting feature of the study is Kiesling's attempt to derive a production model from his results, using the two instructional characteristics found to be highly related to pupil performance. There were IEMs (a measure of the amount of individualized treatment received by the pupil) and the percentage of instruction by a reading specialist. The resulting diagram is reproduced as Figure 10. The asterisks represent observations. The broken line GG was drawn to reflect the experience of 31 projects whose performance levels were within 25% of the mean. The HH line was constructed from 6 projects whose performance level was 40% higher than the mean of the GG group.

Although the Kiesling study does not consider ITV or CAI, it would be interesting to see to what extent a computer providing individualized instruction can substitute for the face-to-face IEMs observed in this study.

e. Hawkridge and Associates: Compensatory Education Programs

Employing an unusual methodology, Hawkridge et al. attempted to identify characteristics associated with successful and unsuccessful compensatory education programs. Although the study can not readily be used to derive production functions, it does suggest a number of input variables which should be examined in future research. Its results are summarized in Table VIII, which indicates the number of times a "component" was found to be present in 18 successful and 25 unsuccessful programs.

D. Summary

Our original expectation was that we would be able to find enough studies using the same media to teach a subject that we would be able to derive some estimates of the "best" combination of teacher and media to produce a given output. This expectation turned out to be naive. Although there have been several hundred studies of media use, few are reported in sufficient detail to be useful, nearly all have merely substituted a television performance for a live lecture and then made comparisons on a standard test which, for all we knew, could have been based on a textbook. There were not many studies which systematically varied the mix of teacher and media and sought differences in output

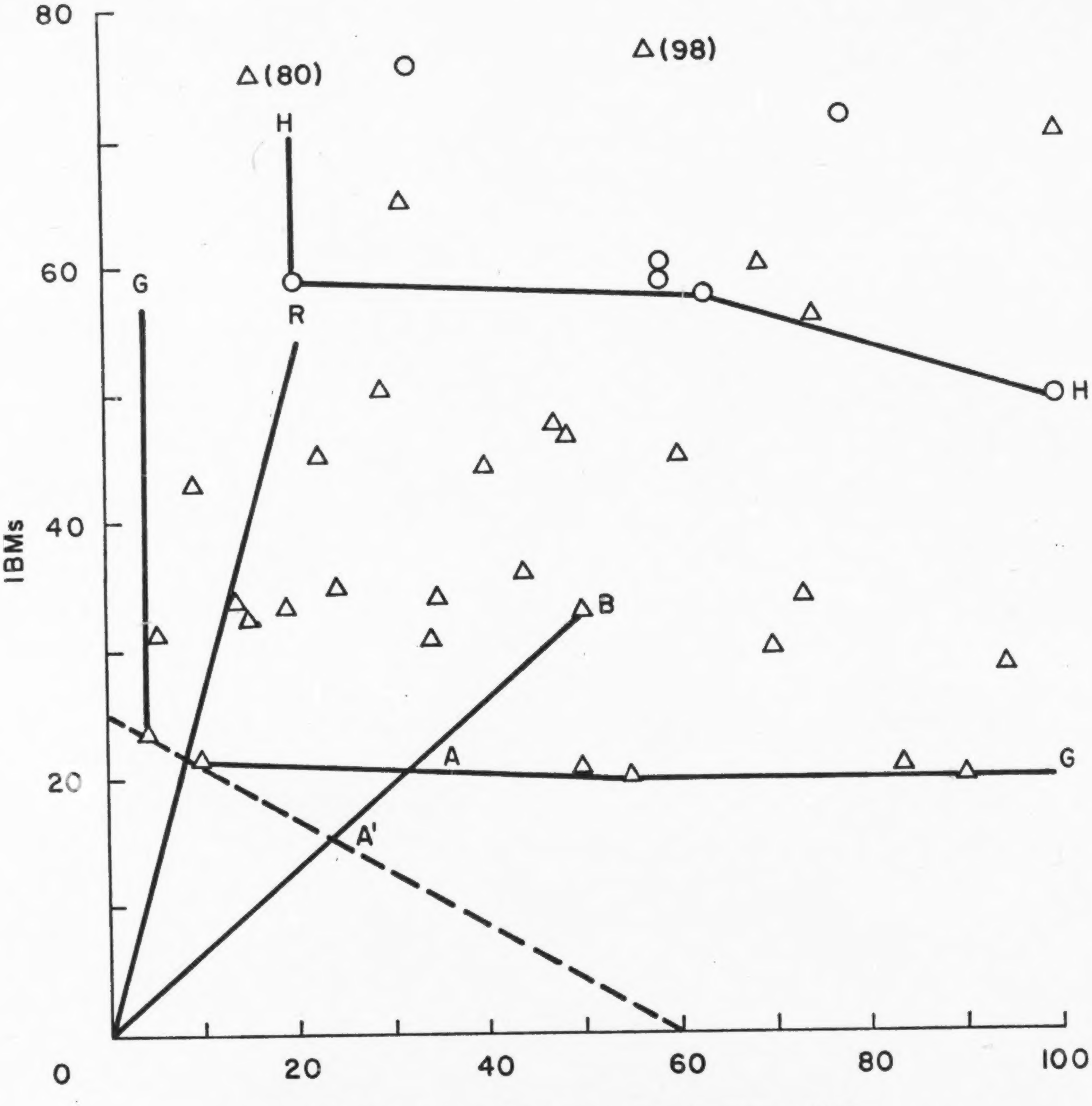

FIGURE 10 ISOQUANTS CONSTRUCTED FOR INSTRUCTION INTENSITY AND PERCENTAGE OF INSTRUCTION GIVEN BY SPECIALIST, HOLDING SOCIO-ECONOMIC FACTORS AND HOURS PLANNING CONSTANT.

(From Kiesling, 1971, p. 43.)

Table VIII

SUMMARY OF HAWKRIDGE'S COMPONENT ANALYSIS, 18 SUCCESSFUL AND 25 UNSUCCESSFUL COMPENSATORY EDUCATION PROGRAMS

	Component	Frequency of Occurrence	
		Successful	Unsuccessful
1.	Qualified Administrator	18/18	13/25
2.	Qualified Counselor(s)	3/18	8/25
3.	Pupil-Teacher Ratio 1:6 to 10	5/18	0.25
4.	Pupil-Teacher Ratio 1:11 to 15	6/18	2/25
5.	Parental Involvement	9/18	6/25
6.	Language (Verbal Skills) Teaching	6/18	12/25
7.	Content-Oriented Approaches	5/18	0/25
8.	Concept Formation Teaching	3/18	0/25
9.	Tightly Controlled Teaching	2/18	0/25
10.	Individual Tutoring	4/18	0/25
11.	Home Visits by Social Worker	5/18	1/25
12.	Cultural Program	1/18	9/25
13.	Games and Toys	2/18	8/25
14.	Language Masters/SRA Reading Labs	7/18	6/25

Source: David G. Hawkridge, G. Kasten Tallmade, Judith K. Lansen, "Foundations for Success in Educating Disadvantaged Children," Final Report, American Institutes for Research in the Behavioral Sciences, Palo Alto, California, Dec. 1968, p. 15.

which could be associated with each type of combination. These are the sorts of studies which must be undertaken to produce data which has much practical utility.

Briefly, we have tried to argue that the difficulties of estimating educational production functions are not insurmountable. The same types of problems which plague the analysis of production in general arise in education, but working at low levels of aggregation and the use of experimental methods may be able to offset these to a significant extent. In fact, as we pointed out above, the ability to use experimental techniques makes the task for the educator-statistician more like that of the agricultural economist, who have estimated successful operational production functions for a long time, than that of the general economist attempting to estimate production functions from unplanned experimental data.

There are, of course, educational outputs which cannot presently be quantified, some of which may never be satisfactorily measured. But many educational objectives, particularly at the elementary and secondary levels, can be and are measured. The difficulty of defining outputs should not be taken as an excuse to do nothing; at a low enough level of aggregation--such as reading or addition--reasonable people can agree on what constitutes acceptable levels of performance. However, educators and parents will have to agree on the desirable outputs, and methods to teach these skills with as few undesirable side effects as possible will need to be investigated. This done, we may find that adverse side effects are more often the result of frustration from not learning anything, than the result of a technique which successfully teaches reading, arithmetic, or some other subject.[1]

---

[1] What is needed to examine this point are studies which use a simultaneous equation framework in which attitudes and achievement may be treated as dependent on each other. See Levin (1970) for a discussion of a similar point.

IV. CONCLUSIONS

Veblen once pointed out that invention is the mother of necessity. Thus, the invention of new forms of instructional media will force the educational system to use the media, or explain why they are not used. The evidence is that the explanations will not be convincing.

Much of the debate over the merits of electronic media for education has been over the ability of the media to deliver a message as well as a teacher. Comprehensive reviews of the literature suggest that conventional lessons, delivered by television, are as effective as those delivered in the classroom. The studies seem to show that, as far as achievement test results are concerned, it does not much matter how the message is delivered.

Television does not seem to make a great deal of difference in the attitudes of students towards courses or school. However, it may be that the students who like television do not like teachers and *vice versa*. A combination of television and teachers might well improve over-all attitudes towards school.

Why then has electronic media not penetrated the school system? We discussed teacher and administrator responses to this question, but other aspects of the question are worth considering. Part of the answer seems to lie in the preoccupation of researchers with the question of whether media can replace the human teacher as dispenser of information. Some other important questions remain. Can the electronic media perform the custodial function or at least help to perform it? This question gets especially important as pupils get older. At the higher grade levels the custodial function is sophisticated, and requires that students be convinced that they should remain in school. This presents a paradox, since electronic media seem to be able to do the same job as human media, but do it quicker, thus making it harder to keep children in school for as many years as we now do.

Second, can we organize education to take advantage of media's ability to allow children (and adults) to pick and choose the time and place for education much more freely than they are presently allowed to do. This is one of the major benefits of supplementing or replacing professional teachers with media.

Third, can we solve the problem of certifying children without the saving grace of a school's blessing? All programs aimed at implementing electronic media as an educational tool have overlooked, and largel fallen on this obstacle. Generally, two solutions to it are possible: offer certificates to people who have obtained their knowledge and skills outside of school and remove the certification function from public schools by prohibiting the publication of student's grades and achievement. Both efforts would, if pushed hard, do much to help the diffusion and expansion of electronic and other new forms of media into education.

Our present use of electronic media in the schools is like forcing the automobile to proceed with a flagman in front. The restriction prohibits the development and use of the new method of getting things done.

We argued above that electronic media will permit greatly increased individualization in schools, and a great widening of the educational system to reach large groups not presently receiving the full benefit of education. But changes will be required in the schools.

Schools are presently charged by law with the incarceration of pupils for a certain number of days per year, and for a certain period of time in each of those days. They are also charged with presenting certain objects (such as textbooks) to students, and, in some states, they are told how many teachers there must be for each student.

These constraints are put on inputs to the school system in the belief that high quality inputs will produce high quality output. However, no data is collected by any state which would allow us to make assessments about the outputs coming out of any school. Hence, the first change in school systems which must take place is one in which states begin to collect data about the achievement of pupils in school. Media can then be assessed in terms of their cost-effectiveness for obtaining pupil achievement.

Second, schools must separate the certification function from the teaching-learning process. The simplest and most effective way to do this is to have skill mastery assessed by some agency other than the teacher and school which tried to teach the skill (C. L. Lessinger, 1970). The old city- and state-wide examinations which are now being dropped all across the country should have served this role, especially had they been graded on the basis of objective and absolute standards. School people, by adopting the normal curve in place of objective standards, subjected themselves to the charge that tests were unfair, undemocratic, fostered competition in students, and were generally bad. The response, to abolish rigorous conditions imposed by curves and competitive grading. However, it has made the rules by which one succeeds in school even more ambiguous than they were when normal curves produced uncertainty.

Third, states need to peg financial support of schools into results obtained rather than to numbers of pupils incarcerated, teacher qualifications and financial needs of school districts. This would simultaneously stimulate experiments with different teaching methods and eliminate the problems associated with paying teachers by degree and experience rather than by competence.

Fourth, schools need to develop management talent in their administrators and teachers. The problem of monitoring student progress, making sure that all students develop to within acceptable limits of quality, and doing both of the above on time and at reasonable cost is a management problem. The conventional wisdom, non-specialized learning content or "human relations" approaches to management found in most schools of educational administration will not do the job.

Finally, we hope this paper has demonstrated the need for further research. To determine educational requirements for technology, we need to know much more about how media and teachers can be used together to teach specific subjects. This will first require identification of those subjects which are critical, and then a coordinated research undertaking. It is not enough to spread large amounts of money all over the country. Data from the experience of the United States Office of Education suggests that very large expenditures of money can simply be swallowed up with neither marked increase in pupil performance nor much addition to our knowledge of the educational process. Lessinger (1970: 8) notes that between 1966-70, 4.3 billion dollars were spent on Title I of the Elementary and Secondary Education Act with no measurable results. Much the same conclusion is reached by Westinghouse in its study of Head Start programs (Cirirelli, 1969) and by OSOE in its study of Title I programs (Education of the Disadvantaged, 1970). In short, there is overwhelming evidence that even large sums of money do not have an impact on the sorts of results that are sought by schools. However, by a research program which is designed to explore input combinations, in a few years time we could learn a great deal about alternative methods of teaching reading, for example, to children of different abilities and backgrounds.

Oettinger's (1969) remarks about policies conducive to economically efficient progress are worth quoting:

> 1. If we want efficiency, we must support promising ideas longer than either private or government programs now permit.
>
> 2. If we want efficiency, we must support risk-taking and cushion failure.
>
> 3. If we want efficiency, then risks, resources, and responsibilities, the 3 R's of educational technology, must be shared by all the partners in the educational enterprise.
>
> 4. If we want efficiency, we must chart our course by human judgment, not exclusively by formula.
>
> 5. If we want efficiency, we must follow through in depth with a small number of diverse alternatives.

We need to follow such policies in examining the potential for educational applications of technology. To date, efforts have been too modest, support too small and too short in duration, and, most important of all, the imagination of technologists has been so limited in attempting to redesign educational facilities and services to take advantage of technology, that really serious efforts to introduce technology into education cannot be said to be taking place in American education.

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APPENDIX

REVIEW OF STUDIES USING INPUT-OUTPUT MODELS TO EVALUATE SCHOOLS

Page

1. Key to Symbols. 53
2. Summary of Studies. 54
3. Studies Summarized in the Appendix. 77

KEY TO SYMBOLS

Δ - significant at 5% level

* - significant at 5% in all cases.

For studies in which one multiple regression is run, Δ is used to indicate the variables which were significant at 5% level. In studies which ran more than one regression (Bowles 1969, 1970 and Kiesling 1967, 1969, 1970), Δ is used for variables which were significant at least 20% of the time and * designates variables which were virtually always significant.

In the Burkhead, Fox and Holland Study: a = Chicago, b = Atlanta, c = Small Town.

SUMMARY OF STUDIES

INPUT VARIABLE	STUDY	OUTPUT MEASURE (dependent vble)	SAMPLE
I. SOCIO-ECONOMIC INPUTS			
A. Family Income 1. median	Δ Burkhead, a	1)11th gr IQ 2)11th gr reading 3)dropouts 4)post HS ed. intentions	n=39 publ. HS in Chicago
	Δ Burkhead, b	1)10th gr med. verbal ach. 2)male dropouts 3)% of Sr. class in school the following yr.	n=22 publ. HS in Atlanta (17 white, 5 black)
	Burkhead, c	1)12th gr reading score 2)dropouts 3)% college attendance 4)12th gr reading residual values(see resume)	n=206 publ. HS in communities (2500-25,000) w/ only one publ HS
2. mean	Hanushek (1970)	3rd gr raw score on SAT (Stanford Achievement Test)	n=1,061 3rd gr pupils in Calif.
3. % of children on AFDC	Kiesling (1971)	Med. gain in reading score per mo. in terms of tenths of gr equivalents & weighted by # of pupils measured for grades 2...5	n=42 elem. schools in Calif. selected from over 700 in CA. Title I compensatory ed. prog.

SE cont...

B. Parents' occupation	* Bowles(1969)	1)reading comprehen 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black 12th graders in USOE Reg 1,2,3 (Proj Talent)
	Δ Hanushek (1970)	3rd gr raw score on SAT	n=1,061 3rd graders in CA
	Kiesling(1967)	ach test scores in basic subjects(IA tests)	n=97 districts in NY
	* Kiesling(1969)	test scores gr gain 6-4 in composite, lang, & math (ITBS)	n=46 urban sch districts in NY (excl. NYC)
	* Kiesling(1970)	test scores for gr 5&8 in compos., lang., & math	n=86 sch districts in NY
	Levin(1971)	1)verbal score 2)efficacy index 3)ed expectations of parents 4)ed aspirations of pupils	n=597 white 6th graders (subset of Coleman report)
	Raymond(1968)	1)ach est score overall ACT 2)Freshman gr PT ave	n=55 counties in W VA (see resume)
	Δ Bassett&Miller(1970)	ITED score on Var subj.	278 3rd&4th graders; 1,000 9th & 11th graders
C. Parents' education	* Bowles (1970)	verbal ach	n=1,000 black 12th graders (Project Talent)
	* Bowles(1969)	(see above)	(see above)
	Jamison, et al(1971)	gain score on math section of SAT	n=58 pupils in one CA school

SE cont.item C. parents' education...

	* Kiesling(1970)	Test scores for gr 5 & 8 in compos., lang., & math	n=86 sch. districts in NY
	Δ Levin(1968)	verbal score of black 12th graders	sample subset of Coleman report; details not specif.
	Δ Levin(1971)	1)verbal score Coleman report 2)efficacy index Coleman report 3)ed. expectations of parents 4)ed. aspirations of pupil	n=597 white 6th graders (subset of Coleman rpt)
	Raymond(1968)	1)achiev. test scores overall ACT 2)Freshman Gr. pt. Ave.	n=55 counties in W. VA. (see resume)
D. Race or ethnic minority	Bowles(1970)	Verbal achievement	n=1,000 black pupils in 12th gr. (Proj. Talent)
	Bowles(1969)	1)reading comprehens. 2)gen. academic ability 3)math II, III scores 4)starting monthly salary	n=1,000 black male pupils in 12th gr. in USOE Reg. 1,2,3, (Proj Talent)
	Δ Hanushek(1970)	3rd gr raw score on SAT	n=1,061 3rd gr pupils in CA.
	Jamison et al(1971)	gain score on math sect. of SAT	n=58 pupils in same CA school
	Kiesling(1971)	Med. gain in reading score per mo. in terms of tenths of gr. equivalents & weighted by # of pupils measured for grades 2...5	n=42 elem. schools in CA selected from over 700 in the Calif. Title I compensatory ed. prog.

SE cont. item D race or ethnic minority...

	Levin(1971)	1)verbal score Coleman rpt 2)efficacy index Coleman rpt 3)ed. expectations of parents 4)ed. aspirations of pupils	n=597 white 6th graders (subset of Coleman rpt)
E. Size of Family	Δ Levin(1968)	verbal score (Coleman report)	black 12th graders sample subset of Coleman report; exact details not specified
	Δ Levin(1971)	(see above)	(see above)
	* Bowles(1968)	Verbal achievment	n=1,000 black pupils in 12th gr(Proj Talent)
	* Bowles(1969)	1)reading comprehens. 2)gen. academic ability 3)math II, III scores 4)starting monthly salary	n=1,000 black male pupils in 12th gr in USOE Reg.1,2,3, (Project Talent)
	Hanushek(1970)	3rd gr raw score on SAT	n=1,061 3rd gr pupils in CA
	Jamison et al(1971)	gain score on math sect. of SAT	n=58 pupils in same CA school
F. Attendance(and motivation)			
1. student transfers	Bowles(1970)	(see above)	(see above)
	Δ Guthrie(1969)	1)reading ability 2)math compreh. 3)verbal facility	n=5,284 6th graders in Mich.

SE cont. item F 1, student transfers...

	Kiesling(1971)	Med gain in reading score per mo. in terms of tenths of gr equivalents & weighted by # of pupils measured for grades 2...5	n=42 elem schools in CA selected from over 700 in CA Title I compensatory ed. Proj.
2. No. of absences	Hanushek(1970)	3rd gr raw score on SAT	n=1,061 3rd gr pupils in CA
3. Family stability	Bowles(1970)	verbal achievement	n=1,000 black pupils in 12th gr(Proj. Talent)
	Bowles(1969)	1)reading comprehens. 2)gen. academic ability 3)math II, III scores 4)starting mo. salary	n=1,000 black male 12th graders in USOE Reg. 1,2,3 (Proj. Talent)
	Levin(1971)	1)verbal scores 2)efficacy index 3)ed expectations of parents 4)ed. aspirations of student	n=597 white 6th graders (subset of Coleman rpt)
4. Preschool attendance	Bowles(1970)	(see above)	(see above)
	Δ Levin(1971)	(see above)	(see above)
G. Home environment and facilities (reading material;TV; telephone, other Durables)			
	Δ Bowles(1970) * Bowles(1969)	(see above) (see above)	(see above) (see above)
	Δ Levin(1968)	verbal score (coleman rpt)	black 12th graders sample (subset of Coleman rpt; details not specified)
	Δ Levin(1971)	(see above)	(see above)

II. PUPIL AND PEER INPUTS

A. Pretest score	Kanner, et al(1956)	1)test of imm. comprehen 2)scores on retention 3)dropouts	124 men in Army power maint. training prog.
	Δ Kiesling(1971)	med gain in reading per mo. in terms of tenths of gr equivalents & weighted for gr 2...5	n=42 elem schools in CA Title I compens. ed Prog.
	Jamison, etal(1971)	gain score on math section of SAT	n=58 pupils in one CA School
B. Age	Jamison,etal(1971)	(see above)	(see above)
	Δ Levin(1971)	1)verbal score 2)efficacy index 3)ed expect of parents 4)ed. aspirations of pupils	n=597 white 6th graders (subset of Coleman report)
C. Sex	Δ Hanushek(1970)	3rd gr raw score on SAT	n=1,061 3rd gr pupils in CA
	Levin(1971)	(see above)	(see above)
	Δ Bassett &Miller(1970)	ITED score on var subj.	278 3&4th gr elem students; 1,000 9th &11th graders
D. Pupils' general ability			
1. raw test score(verbl)	Jamison,etal (1971)	(see above)	(see above)
2. previous math GPA	Jamison,et al(1971)	"	"
3. progress grade to grade	Δ Hanushek(1970)	(see above)	(see above)
4. IQ	Δ Bassett&Miller(1970)	(see above)	(see above)

Pupil and Peer cont.

E. Student attitude			
1. Educational aspiration (yrs)	Jamison et al(1971)	gain score on math section of SAT	n=58 pupils in same school
2. Student concept of self	Δ Bowles(1970)	Verbal achievement (Proj Talent)	n=1,000 black 12th graders
3. Student sense of control of environment	Δ Bowles(1970)	(see above)	(see above)
F. Longivity of program	Kiesling(1971)	med. gain in reading score per mo. in terms of tenths of gr. equivalents & weighted by # of pupils measured for grades 2...5	n=42 elem schools in CA selected from over 700 in CA Title I compens. ed. prog.
G. Peer Effect			
1. Ave. occupation of parents index	Kiesling(1969)	test scores gr gain 6-4 in comsposite, language, math(ITBS)	n=46 urban sch districts in NY (excl. NYC)
2. Ave. pupil intelligence	* Kiesling(1967)	ach test scores in basic subjects	n=97 districts in NY

III. SCHOOL INPUTS (except teachers)

A. Expenditure Level

1. School Building

a. Building age	Burkhead,a	1)11th gr IQ 2)11th gr reading 3)dropouts 4)post HS ed intentions	n=39 publ. HS in Chicago
	Burkhead,b	1)10th gr med verbal ach 2)male dropouts 3)%of Sr. class in school the following yr.	n=22 publ HS in Atlanta (17 white, 5 black)
	Δ Burkhead,c	1)12th gr reading score 2)dropouts 3)% college attendance 4)12th gr reading residual (see resume)	n=206 publ. HS in communities(2500-25,000) w/ only one HS.
	Δ Bowles(1969)	1)reading comprehens. 2)gen. academic ability 3)math II, III scores 4)starting mo. salary	n=1,000 black male pupils in 12th gr in USOE Region 1,2,3,(proj Talent)
	Δ Guthrie(1969)	1)reading ability 2)math comprehen. 3)verbal facility	n=5,284 6th graders in Mich.
	Δ Plowden Report(1967)	(not reported)	British elem. school pupils
b. Building size	Δ Guthrie(1969)	(see above)	(see above)
	Δ Katzman(1968)	1)attendance 2)school holding power 3)reading ach. 4)special school entrance exam	Boston elem school students

school inputs,III, expenditure level, school building size cont..

	Raymond(1968)	1)achievement test scores-overall ACT 2)Freshman Gr Pt Ave	n=55 counties in W. VA (see resume)
c. Bldg value/pupil	Cohn(1968)	gain for composite score 12-10 on Iowa Test of Ed. Development	n=377 IA HS districts
	Kiesling(1969)	test scores gr gain 6-4 in composite,lang, & math (ITBS)	n=46 urban sch districts in NY (excl. NYC)
2. Current expenditure/ pupil	Burkhead b	1)10th gr med verbal 2)male dropouts 3)% of Sr class in school the following yr	n=22 publ HS in Atlanta (17 white, 5 black)
	Burkhead, c	1)12th gr reading score 2)dropouts 3)% college attendance 4)12th gr reading residual (see resume)	n=206 publ HS in communities (2500-25,000) w/ one publ HS
	Δ Benson(1965)	reading ach test	Calif. 5th grade in 249 districts
	Δ Goodman(1959)	achievement test scores	70,000 7th and 11th graders in 102 NY districts
	Cohn(1968)	(see above)	(see above)
	Kiesling(1967)	ach test in basic subjects(ITBS)	n=97 districts in NY
	Raymond(1968)	1)achiev. test scores overall ACT 2)Freshman Gr PT Ave	n=55 counties in W VA (See resume)

School inputs, III, current expenditures/pupil cont..

	Δ Mollenkopf & Melville (1956)	ach test scores	17,000 9th and 12th graders
	Δ Ribich(1968)	ach test scores	Proj Talent sample
B. Allocation of current expenditures			
1. Exp. on administrators (principals, clerks, supervisors, maint. pers.)	Burkhead,a	1)11th gr IQ 2)11th gr reading 3)dropouts 4)post HS ed. intent.	n=39 publ. HS in Chicago
	Δ Bowles(1969)	1)reading compreh. 2)gen. academic ability 3)math II, III scores 4)starting monthly salary	n=1,000 black male pupils in 12th gr in USOE Reg 1,2,3 (PROJ Talent)
	Δ Benson(1965)	reading ach test	Calif. 5th graders in 249 districts
	* Kiesling(1969)	test scores gr gain 6-4 in composite, lang. & math(ITBS)	n=46 urban sch districts in NY (excl NYC)
	Δ Kiesling (1970)	test scores for gr 5&8 in comp., lang., & math	n=86 sch dist in NY
2. Special staff (librarians, guidance couns., dvrs ed,..)	Burkhead, a	(see above)	(see above)
	Δ Goodman(1959)	ach test scores	70,000 7th & 11th graders in 102 NY districts
	Δ Mollenkopf&Melville (1956)	(see above)	(see above)
3. Library expenditure (or size)	Burkhead,a Burkhead,b	(see above) 1)10th gr med verbal 2)male dropouts 3)% of Sr class in school the following yr	(see above) n=22 publ HS in Atlanta (17 white, 5 black)

School inputs, III, allocation of exp., library cont...

	Burkhead, c	1)12th gr reading 2)dropouts 3)% college attendance 4)12th gr reading residual (see resume)	n=206 publ. HS in communities(2500-25,000) w/ one publ HS
	Bowles(1970)	verbal achievement	n=1,000 black 12th graders (Proj. Talent)
	Δ Guthrie(1969)	1)reading ability 2)math. compreh. 3)verbal facility	n=5,284 6th graders in Mich.
	Kiesling(1969)	test score gr gain 6-4 in composite, lang,&math (ITBS)	n=46 urban sch districts in NY (excl. NYC)
	Levin(1971)	1)verbal score 2)efficacy index 3)ed. expectations of parents 4)ed. aspirations of students	n=597 white 6th graders (subset of Coleman rpt)
	Raymond(1968)	1)achiev. test scores overall ACT 2)Freshman gr pt ave	n=55 counties in W VA (see resume)
	Δ Thomas(1962)	ach test	national sample 10th & 12th graders from Proj Talent
4. Other facilities (esp. science labs; specialized facil.vs. classroom)	Δ Bowles(1970)	verbal achievement	n=1,000 black 12th graders (Proj Talent)
	Δ Bowles(1969)	1)reading compreh. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black male 12th graders in USOE Reg 1,2,3 (Proj Talent)

	Burkhead,a	1)11th gr IQ 2)11th gr reading 3)dropouts 4)post HS ed. intent.	n=39 publ. HS in Chicago
	Δ Guthrie(1969)	1)reading ability 2)math comprehen. 3)verbal facility	n=5,284 6th graders in Mich.
	Δ Kiesling(1971)	med gain in reading score per mo. in terms of tenths of gr equivalents & weighted by # of pupils measured for grades 2...5	n=42 elem schools in CA in CA Title I compens. ed. program.
	Δ Levin(1968)	verbal score (Coleman report)	black 12th graders sample; subset of Coleman report (details not avail.)
C. Scale			
1. Enrollment	Bowles(1970)	verbal achievement	n=1,000 black students in 12th grade (Proj Talent)
	Bowles(1969)	1)reading comprehens. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black male pupils in 12th gr in USOE Reg 1,2,3 (Proj. Talent)
	Burkhead,a	1)11th grade IQ 2)11th grade reading 3)dropouts 4)post HS ed intentions	n=39 publ. HS in Chicago
	Burkhead,b	1)10th grade verbal 2)male dropouts 3)% of Sr. class in school following yr	n=22 publ. HS in Atlanta (17 white, 5 black)
	Burkhead,c	1)12th gr reading score 2)dropouts 3)% college attendance 4)12th gr reading residual	n=206 publ HS in small towns

School inputs, III, enroolments cont...

	Cohn(1968)	gain for composite score 12-10 on Iowa test of ed. Devel.	n=377 IA HS districts
	Δ Guthrie(1969)	1)reading ability 2)math comprehens. 3)verbal facility	n=5,284 6th graders in Mich.
	Δ Katzman(1968)	1)attendance 2)school holding power 3)reading ach. 4)special school entrance exam.	Boston elem school students
2. District size & growth	Δ Kiesling(1967)	ach test scores in basic subjects(ITBS)	n=97 districts in NY
D. Class Size			
1. # of pupils in class	Burkhead,c	1)12th gr reading 2)dropouts 3)% college attendance 4)12th gr reading residual(see resume)	n=206 publ HS in small towns
	Δ Bowles(1969)	1)reading comprehens. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black male pupils in 12th gr in USOE REG 1,2,3 (Proj Talent)
	Δ Mollenkopf & Melville (1956)	ach test scores	17,000 9th & 12th graders

School inputs,III, class size cont...

2. Pupil/teacher ratio	Burkhead, a	1)11th gr IQ 2)11th gr reading 3)dropouts 4)post HS ed intentions	n=39 publ. HS in Chicago
	Burkhead, b	1)10th gr verbal 2)male dropouts 3)% of Sr. class in school following yr.	n=22 publ. HS in Atlanta (17 white, 5 black)
	Bowles(1970)	verbal ach.	n=1,000 black students in 12th gr (Proj Talent)
	Cohn(1968)	gain for composite score 12-10 on Iowa test of ed. devel.	n=377 IA HS districts
	Δ Katzman(1968)	1)attendance 2)school holding power 3)reading ach. 4)special school entrance exam	Boston elem school students
	Δ Kiesling(1969)	test score gain 6-4 in composite,lang.& math (ITBS)	n=46 urban sch districts in NY (excl. NYC)
	Kiesling(1970)	test scores for gr5&8 in comp, lang. & Math	n=86 sch dist in NY
	Δ Mollenkopf&Melville (1956)	ach test score	17,000 9th & 12th graders
	Raymond(1968)	1)ach test scores-overall ACT 2)Freshman GR Pt Ave	n=55 counties in W VA (see resume)

School inputs,III, class size cont..

3. Teacher load	Δ Cohn(1968)	gain for composite score 12-10 on Iowa test of ed. devel.	n=377 IA HS districts
	Raymond(1968)	1)ach test scores overall ACT 2)Freshman gr pt ave.	n=55 counties in W VA (see resume)
E. School administration and organization of the program			
1. Curriculum			
a. Content	Bowles(1970)	verbal ach.	n=1,000 black 12th graders (Proj Talent)
	Bowles(1969)	1)reading comprehen. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black male 12th graders in USOE Reg 1,2,3 (Proj Talent)
	Cohn(1968)	(see above)	(see above)
	Δ Shaycoft(1967)	btry of 42 aptitude & ach tests	6,500 9th &12th graders in 108 schools
b. Organization (tracking etc)	Bowles(1970)	(see above)	(see above)
	Δ Bowles(1969)	(see above)	(see above)
	Kiesling(1971)	med gain reading score per mo. in terms of tenths of gr. equivalents & weighted by # of pupils measured for gr 2...5	n=42 elem schools in CA Title I compens. Ed. Prog.
2. Admin. planning & teamwork			
	Kiesling(1971)	(see above)	(see above)

School inputs, III, curriculum cont..

3. Program length and intensity			
	Bowles(1970)	verbal ach	n=1,000 black 12th graders (Proj Talent)
	Bowles(1969)	1)reading comprehen. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black male 12th graders in USOE Reg 1,2,3 (Proj Talent)
	Kiesling(1971)	med gain reading score per mo. in terms of tenths of gr. equivalents & weighted by # of pupils measured for gr 2...5	n=42 elem schools in CA Title I compens. ed. Prog.
4. Method of presentation (how and/or by whom was the material presented to the students)	Δ Bowles(1969)	(see above)	(see above)
	Δ Kiesling(1971)	(see above)	(see above)
	Kanner,et al(1956)	1)test of immediate recall 2)scores on retention 3)dropouts	124 men in Army power maint. training program
	Jamison,etal(1971)	gain score on math section of SAT	n=58 pupils in one CA school
	Atkinson(1968)	CA ach test; Hartley Reading test	over 100 1st graders in Brentwood School(Palo Alto)
	Suppes&Morningstar (1969)	math section of SAT	1,000 pupils in 4 CA schools grades 1...6

IV. Teacher Inputs

a. Salary	Δ Benson(1965)	reading ach test	CA 5th grade in 249 dist.
	Bowles	verbal achievement	n=1,000 black 12th graders
	Bowles(1969)	1)reading comprehens. 2)gen. academic ability 3)math II, III 4)starting mo. salary	n=1,000 black pupils in 12th grade in USOE Reg 1,2,3 (Proj. Talent)
	Δ Cohn(1968)	gain for composite score 12-10 on IA test of ed. development	n=377 IA HS districts
	Δ Burkhead,b	1)10th gr med verbal 2)male dropouts 3)% of Sr class in school the fol. yr.	n=22 publ HS in Atlanta (17 white, 5 black)
	Δ Burkhead,c	1)12th gr reading score 2)droupouts 3)% college attendance 4)12th gr reading residual (see resume)	n=206 publ HS in communities (2500-25,000) w/one publ HS
	Δ Kiesling(1969)	test scores gr gain 6-4 in composite, lang,& math(ITBS)	n=46 urban sch districts in NY (excl NYC)
	* Kiesling(1970)	test scores for gr 5&8 in compos., lang., & Math	n=86 sch districts in NY
	Δ Levin(1968)	verbal score	sample subset of black 12th graders from Coleman report (details not specif.)

Teacher inputs, IV, salary cont..

	Δ Raymond(1968)	1)ach test overall ACT 2)Freshman gr pt ave	n=55 counties in W VA (see resume)
	Δ Thomas(1962)	ach test	national sample 10th & 12th graders from Proj Talent
B. Years of experience	Bowles(1970)	verbal ach	n=1,000 black 12th graders (Proj Talent)
	Δ Burkhead, a	1)11th gr IQ 2)11th gr reading 3)dropouts 4)post HS ed intentions	n=39 publ. HS in Chicago
	Δ Burkhead, c	1)12th gr reading 2)dropouts 3)% college attendance 4)12th gr reading residual(see resume)	n=206 publ. HS in communities(2500-25,000) w/one publ. HS
	Δ Goodman(1959)	ach test scores	70,000 7th & 11th graders in 102 NY districts
	Δ Guthrie (1969)	1)reading ability 2)math comprehens. 3)verbal facility	n=5,284 6th graders in Mich.
	Hanushek(1968)	verbal ability test	white 6th graders in 471 schools and black 6th graders in 242 schools
	Hanushek(1970)	3rd gr raw score on SAT	n=1,061 3rd gr pupils in CA
	Δ Kiesling(1970)	test scores for gr5&8 in compos., lang, &math	n=86 sch districts in NY
	Δ Katzman(1968)	1)attendance 2)school holding power 3)reading ach. 4)special school entrance exam	Boston elem school students

Teacher inputs, IV, yrs of experience cont...

	Levin(1968)	verbal score	sample subset of black 12th graders of Coleman report; (details not spec)
	Δ Levin(1971)	1)verbal score 2)efficacy index 3)ed aspirations of parents 4)ed. asperations of pupil	n=597 white 6th graders (subset of Coleman rpt)
	Δ Plowden Report(1967)	(not reported)	British elem school pupils
	Δ Thomas(1962)	ach test	national sample 10th &12th graders from PROJ TALENT
C. Quality of teacher"s education			
1. Degree level/ semester hours	Burkhead, a	1)11th gr IQ 2)11th gr reading 3)dropouts 4)post HS ed intentions	n=39 publ HS in Chicago
	Δ Plowden Report(1967)	(see above)	(see above)
	Bowles(1970)	verbal ach	n=1,000 black 12th graders (Proj Talent)
	Δ Bowles(1969)	1)reading comprehens. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black 12th graders in USOE Reg 1,2,3 (Proj Talent)
	Cohn(1968)	gain for composite score 12-10 on IA test of ed devel.	n=377 IA HS districts

Teacher inputs, IV, teacher education quality, degree level cont..

	* Hanushek(1970)	3rd gr raw score on SAT	n=1,061 3rd gr pupils in CA
	Δ Katzman(1968)	1)attendance 2)school holding power 3)reading ach. 4)special school entrance exam	Boston elem school students
	Kiesling(1970)	test scores for gr5&8 in composite, lang.,& math	n=86 sch districts in NY
2. College quality teacher attended			
	Bowles(1970)	verbal ach	n=1,000 black 12th graders (Proj. Talent)
	Δ Levin(1971)	1)verbal score 2)efficacy index 3)ed aspirations of student 4)ed expectations of parents	n=597 white 6th graders (subset of Coleman report)
3. Certification	Bowles(1969)	1)reading comprehens. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black 12th graders in USOE Reg 1,2,3 (Proj Talent)
	Δ Kiesling(1970)	(see above)	(see above)
4. Supplementary training & review	Δ Hanushek(1970)	(see above)	(see above)
	Kiesling(1971)	med gain reading per mo. in terms of tenths of gr. equivalents & weighted by # of pupils measured for gr 2...5	n=42 elem schools in CA Title I compens. ed prog.

Teacher inputs, IV, cont..

D. Teacher verbal ability	* Bowles (1970)	verbal ach	n=1,000 black 12th graders (Proj. Talent)
	* Bowles (1969)	1)reading comprehens. 2)gen academic ability 3)math II, III 4)starting mo. salary	n=1,000 black 12th graders in USOE Reg 1,2,3 (Proj Talent)
	Δ Guthrie (1969)	1)reading ability 2)math comprehens. 3)verbal facility	n=5,284 6th graders in Mich/
	Hanushek (1968)	verbal ability test	white 6th graders in 471 schools and black 6th graders in 242 schools
	Δ Hanushek (1970)	3rd gr raw score on SAT	n=1,061 3rd gr pupils in CA
	Δ Levin (1968)	verbal score	sample subset of black 12th graders of Coleman report (details not spec)
	Levin (1971)	1)verbal score 2)efficacy index 3)ed expectations of parents 4)ed aspirations of pupils	n=597 white 6th graders (subset of Coleman report)
E. Method of teaching			
1. Time spent in guidance	Δ Bowles (1970) Δ Bowles (1969)	(see above) (see above)	(see above) (see above)
2. Time spent in discipline	Δ Hanushek (1970)	(see above)	(see above)
3. Amount of homework	Bowles (1970)	(see above)	(see above)

Teacher inputs, IV, method of teaching cont...

4. Amount of individualized instruction	Kiesling(1971)	med gain reading per mo. in terms of tenths of gr. equivalents & weighted by # of pupils measured for gr 2...5	n=42 elem schools in CA Title I prog.
5. Degree of student orientation	Δ Goodman(1959)	ach test scores	70,000 7th & 11th graders in 102 NY districts
F. Motivation of teacher			
1. Job satisfaction and turnover rate	Bowles(1970)	verbal ach	n=1,000 black 12th graders (Proj Talent)
	Burkhead, b	1)10th gr verbal ach 2)male dropouts 3)% of Sr. class in school the fol yr.	n=22 publ HS in Atlanta (17 white, 5 black)
	Δ Guthrie(1969)	1)reading ability 2)math comprehens. 3)verbal facility	n=5,284 6th graders in Mich.
	Δ Katzman(1968)	1)attendance 2)school holding power 3)reading ach 4)special school entrance exam	Boston elem school students
	Levin(1971)	1)verbal score 2)efficacy index 3)ed expectations of parents 4)ed. aspirations of pupil	n=597 white 6th graders (subset of Coleman report)
	Raymond(1968)	1)ach test scores overall ACT 2)Freshman gr pt ave	n=55 counties in W. VA. (see resume)

Teacher inputs, IV, teacher motivation cont..

2. Teacher socio-econ status	Bowles(1970)	verbal ach	n=1,000 black 12th graders (Proj Talent)
	Levin(1971)	1)verbal score 2)efficacy index 3)ed. expectations of parents 4)ed. aspirations of pupils	n=597 white 6th graders (subset of Coleman rpt)
3. Degree of teacher localism			
	Bowles(1970)	(see above)	(see above)

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